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# SERVO

SERVO MAGAZINE

FOR THE ROBOT INNOVATOR

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July 2013

## Inside The ROBOT COMBAT League

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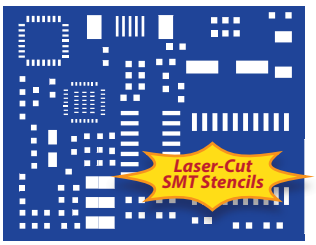


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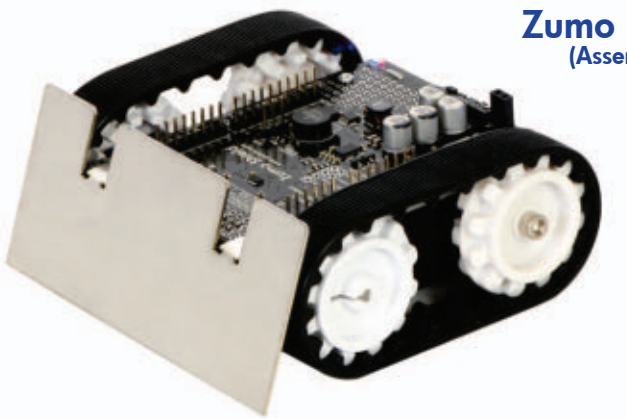

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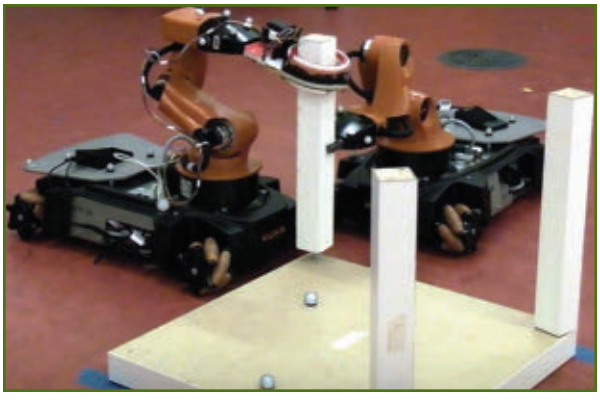

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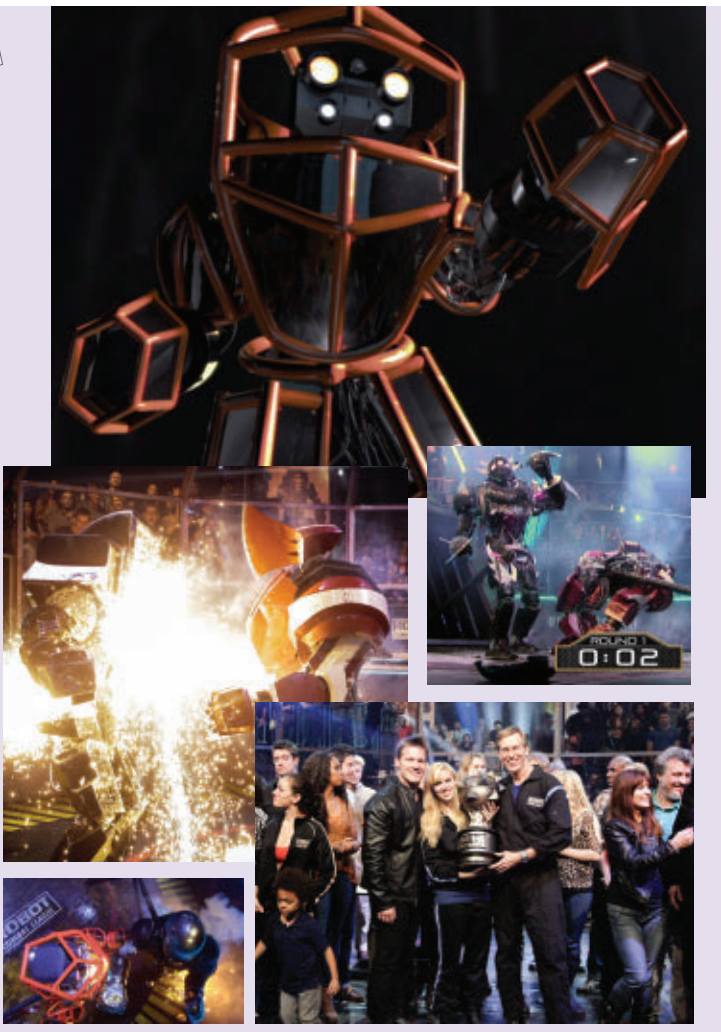


*All Robot Combat League photos are courtesy of Mark Setrakian and **Syfy.com**.*


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See what it took to get from a ready-for-action printer to a first print.

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# Mind / Iron

*by Bryan Bergeron, Editor*

## Starting from SCRATCH

"How do I start my students/children down the road of robotics?" is a common question in my inbox. It's a difficult question to answer. Not for lack of options, but because there are so many options available. As with most things, the 'best' solution depends on budget, existing infrastructure, and the overall goal.

For example, let's say you're a first grade teacher with a few desktop computers in your classroom. If your goal is to introduce programming concepts and eventually branch out to sensors and hardware control, then you should explore the SCRATCH language. SCRATCH is a graphical programming language that makes it easy for anyone five years and older to create interactive stories, animations, games, music, and art, and then to share their creations on the Web.

Best of all, SCRATCH is free. It was developed at the MIT Media Lab with financial support from the National Science Foundation, Microsoft, Intel Foundation, MacArthur Foundation, Google, Iomega, and the MIT Media Lab research consortia. Check out the site (**info.scratch.mit.edu**) for more information, including YouTube tutorials, hundreds of examples, books, and hardware. Version 2.0 is currently in beta but the full SCRATCH 2.0 should be available by the time you read this.

If your goals include teaching young children or students how to integrate sensors and effectors in software, then consider the PicoBoard ($45) from SparkFun. The SCRATCH-compatible board — based on an ATmega328 running at 16 MHz — contains a phototransistor, microphone, button, and slider, as well as four additional inputs that can sense electrical resistance. Setup is simple — connect the USB device to your computer, download the drivers, and start programming. Motors, additional sensors, and other hardware add-ons (available from the SCRATCH store) are inexpensive. Another great feature is the PicoBoard Simulator program (**http://scratch.mit.edu/projects/chalkmarrow/188919**) that allows you to experiment with a simulated board before you actually buy one.

I like the SCRATCH/PicoBoard combination, in part because there's a natural growth path to the Processing/Arduino combination. Processing shares many attributes with SCRATCH, but is much more powerful. It's also text based, and so may be more intimidating for novices.

If your students/kids are a little older, then consider the book *Python for Kids: A Playful Introduction to Programming*. I wish that this book had been available when I first learned the language. Python is free and runs on the most popular operating systems. However, if you or your school don't have a computer available, then consider investing in a few Raspberry PI microcontrollers ($25). The downside of this combination is that you need to create a desktop environment — that means a mouse, keyboard, and HD monitor. While miniature monitors are available, a decent one will cost $100 and up. Still, it's hard to beat the Raspberry PI's mix of affordability and power. I paid over $1,000 for a less capable Linux board to use on one of my robot projects only a few years ago. Unlike that board, there are a variety of shields — including Arduino-compatible shields — available for the Raspberry PI. SV

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# BIO-FEEDBACK

Dear *SERVO*:

VEX Robotics would like to address a factual error and other inaccurate statements made about the VEX Robotics Design System in last month's article featuring MATRIX Robotics.

The price for the VEX Robotics Dual Control Starter Kit that was described in the article is $499.99, not $799.99. After speaking to the article's author, it became clear he meant to highlight the Classroom & Competition Mechatronics Kit, which is a complete robotics kit for $799.99. This kit — unlike other educational robotics platform base sets — has everything needed to build a fully functional, driver controlled, autonomous or dual control robot — including structural and motion components, hardware, joystick, microcontroller, sensors, batteries, and charger.

Also, the author's assertion that quality and flexibility have been sacrificed for affordability reasons is not correct. The VEX Robotics Design System has become the platform of choice for tens of thousands of middle schools, high schools, and universities around the world due to its affordability, accessibility, scalability and quality.

Mobile robots and other projects built with the VEX Robotics Design System can be built for strength and without any sign of flimsiness. Of course, robot design, appropriate material selection for the application, and correct assembly factor in to the robot's strength, and durability, but when used correctly VEX is as durable as any other educational robotics platform.

Customizable structural components and add-ons, unique motion accessories, and advanced sensor capabilities make building with VEX almost limitless. We are constantly amazed at the unique and creative robots that students build with VEX — both in the classroom and as an extracurricular competition by over 7,000 VEX Robotics Competition teams.

Our customers are encouraged to contact us directly with any questions, comments, complaints, or ideas. We listen to all suggestions, fix any problems that exist, and promise continuous improvement and innovation as we strive to be the best educational robotics provider in the world.

**Paul Copioli**
**President**
**VEX Robotics, Inc.**

Dear *SERVO*:

In the May 2013 Combat Zone, Zac O'Donnell mentions he uses Alibre Design's 3D CAD package. I was wondering what version he uses — the professional or personal edition. If he uses the personal edition, I would like to know if that version has satisfied his needs at least for his robotics hobby. Thanks!

**Dave Pollatta**
**Ontario, NY**

*I started with Alibre Design Standard 2011 and later upgraded to Alibre Design 2012. There is no Alibre Design Standard — only Personal, Pro, and Expert — so what I have is somewhere between Personal and Expert. I have read through the feature list for Personal and I think everything I do can be accomplished with that version. I'm not exactly sure what features I have on top of those, but I don't think I use them. If I had been unable to upgrade, I would have purchased the Personal Edition, and I think it is well worth it. The only feature I find myself wishing I had is some form of rudimentary animation. It would make explaining my designs much easier than the poor man's stop-motion I have to do with screenshots now. That feature is only available in Alibre Expert though, and the minor inconvenience is certainly not worth the added cost to me.*

*Zac*

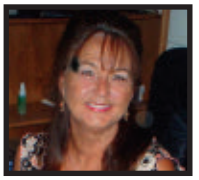
Dear *SERVO*:

I had the chance to talk to Mark Setrakian at the recent RoboGames about the machines he designed for the Robot Combat League. Basically he designed the common chassis for all of the robots in CAD. I asked him who had designed the hydraulic system and he said, "ME." I was amazed since he mentioned that he had no prior experience with hydraulics. I asked him how long he had been designing hydraulic systems and he told me, "Well it's my first time." I said, "You have to be freaking kidding me!"

He then told me that when he asked for help, that many professional hydraulic venders told him what he had planned was impossible. Of course, Mark invented a solution and changed the known world out of necessity. I learned a lot from this conversation. Ignorance to the "known impossible" means nothing to an artist and that's what changes our reality. Mark told me that all of the robots, and control and power systems were built from scratch in less than four months by him and his team. I stood there drooling having shared a YODA moment with a true master of things. It doesn't happen often, but when some folks play by their *own* rules, we can all learn from them.

Mark reinforced something I have learned from other artists. Known science is often only a theory, and the rules that are known are meant to be broken when needed. This notion makes me smile from ear to ear. When in doubt, try something different and see what happens. That is how we learn. Maybe nothing is impossible when we ignore the rules that some believe in.

**Steven Nelson**



# Robytes

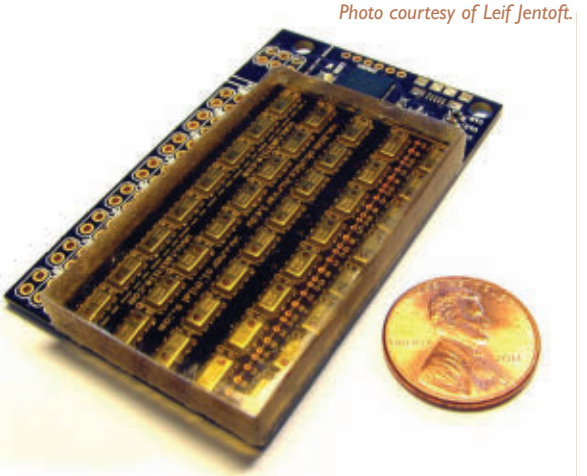
by Jeff and Jenn Eckert

Discuss this article in the *SERVO Magazine* forums at http://forum.servomagazine.com.

## Touchy-Feely for Less

A perennial dilemma in the robotics world is how to equip grippers with touch sensitivity to keep them from dropping or crushing things. Several viable technologies exist, based on things like piezoelectric and capacitive devices, but "... despite decades of research, tactile sensing hasn't moved into general use because it's been expensive and fragile," noted Leif Jentoft, a graduate student at the Harvard School of Engineering and Applied Sciences (SEAS, **seas.harvard.edu**). "It normally costs about $16,000, give or take, to put tactile sensing on a research robot hand. That's really limited where people can use it." Now, however, Jentoft and co-creator Yaroslav Tenzer have come up with a tactile array that — being based on relatively cheap MEMS barometers — should put tactile sensing within reach of a wider range of inventors, educators, and bot builders in general. Called "TakkTile," it consists of barometric sensors (commonly used in cell phones and GPS units) placed in a vacuum-sealed layer of rubber that protects them from direct pressures up to 25 lb. The result is a device that can allow a mechanical hand to "pick up a balloon without popping it" or "pick up a key and use it to unlock a door." Other potential applications include various electronic and medical devices and even toys. The sensors can be built using standard printed circuit board fabrication equipment, along with a vacuum chamber. Harvard plans to license the technology, so if you're interested, get in touch with Harvard's Office of Technology Development (**otd.harvard.edu**).

*Photo courtesy of Leif Jentoft.*



***An 8 x 5 tactile array provides gram-level sensitivity.***

## Prototype Power Line Inspector

Back in 2012, we covered LineScout — a bot used by Hydro Québec to inspect 18,000 miles of Canadian power lines. The 250 lb system includes a robotic arm that can wrap and clamp frayed wires, and even tighten bolts on equipment attached to the wires. But what if you're Podunk Power and you don't need and can't afford such a behemoth? The solution may be SkySweeper — a cheap alternative built with off-the-shelf electronics and plastic components produced on a 3D printer. Designed by mechanical engineers at the University of California, San Diego's Coordinated Robotics Lab (**http://fccr.ucsd.edu**), it is basically a motor-driven elbow that opens and closes clamps to move along the wires like an inchworm, searching for damage. According to grad student Nick Morozovsky, "Current line inspection robots are large, complex, and expensive. Utility companies may also use manned or unmanned helicopters equipped with infrared imaging to inspect lines. This is much simpler." The device shown is a small-scale prototype, but Morozovsky says it could be scaled up for less than $1,000. SkySweeper could also be fitted with induction coils to power itself directly from the power line, allowing it to be deployed continuously for weeks or months.

*Photo courtesy of UC San Diego Jacobs School of Engineering.*

***The SkySweeper power line inspector.***

## The Future of Clothes Shopping?

If you happen to be extremely shy, antisocial, or generally misanthropic, Nadia Shouraboura has a treat for you. In August of last year, she left a highly remunerative job at Amazon, kicked in $5 million of her own money, and founded Hointer (**www.hointer.com**) — a high-tech haberdashery that employs mobile phones and robots instead of a human sales staff. The original Seattle location seems to be enjoying some level of success, as several more outlets are in the works.

The concept is fairly simple. You walk in the door, download the Hointer shopping app to a cell phone, and wander around the meagerly appointed store until you find an article of clothing (currently pretty much limited to high-priced jeans) that suits your fancy. You then aim the cell phone's camera at a tag on the pants to add it to your "cart," after which the app directs you to a vacant fitting room where the clothing is already waiting at the bottom of a chute. After trying the pants on, you can opt to buy them or just drop them down the reject hole. You can also choose to have a different size delivered. The entire shopping experience is conducted without human intervention, which allows you to avoid contact with surly sales staff and allows Hointer to avoid hiring any.

Curiously, the company is hush-hush about the exact nature of the robotic equipment that accomplishes all of this, revealing only that it comes from "a totally awesome German equipment manufacturer." Since Shouraboura worked as the head of supply chain and fulfillment technologies at Amazon, it is likely derived from that massive operation. On the other hand, it could be just a crew of unemployed Keebler elves running around upstairs. Either way, some are predicting that the Hointer concept will revolutionize the way people shop. Well, maybe.

*Pants are displayed on racks instead of shelves in the Hointer robotic store.*

## Chewing Up the Mint?

If you have been looking at the Mint floor cleaning robot but hesitate to pay up to $250 for an appliance that doesn't work all that well, there is good news. Now, you only have to pay $39.99 for an appliance that doesn't work all that well (or $34.99 if you download a coupon from the website). Now available is the O-Duster robot from the mop and broom folks at O-Cedar (**www.ocedar.com**). The device rotates as it travels around the floor, picking up dust and hair with a disposable electrostatic cloth. Suitable for all hard surfaces, it employs an auto-navigation feature to avoid obstacles, and operates on your choice of a 30- or 120-minute cleaning cycle. Reportedly, some Walmart stores have taken them off the shelves because the motors tend to burn out in a relatively short time, but hey, isn't anything that gives you more couch time with the Lifetime channel worth a try? **SV**

*O-Cedar's $40 O-Duster sucks up dust and hair.*

# GEERHEAD

by David Geer

Contact the author at geercom@windstream.net

# Giant Robot Jellyfish

## *Cyro Swims Better Than Its Smaller Cousins*

**Using eight linear actuators and eight electric motors, the five foot, seven inch, 170 lb Cyro moves its arms downward which, in turn, pushes the outer circle of its attached silicon membrane so that it descends, creating a thrusting motion to enable its dynamic swimming capabilities.**

## The Navy Enlists Virginia Tech and a Robot Jellyfish

The US Navy commissioned Cyro: a man-sized robot jellyfish for underwater surveillance and monitoring, which was engineered by Virginia Tech researchers and scientists from other schools across the country. The autonomous and realistic creature was fashioned after the likeness of the lion's mane jellyfish (Cyanea capillata) or hair jelly — the largest known species of jellyfish.

The robotic duplicate is five feet, seven inches in size, and weighs in at 170 lbs. The largest lion's mane jellyfish on record washed up on the shore of Massachusetts Bay in 1870, and had a bell (body) with a diameter of seven feet, six inches (2.29 m), and tentacles 120 feet (37 m) long. Cyro itself has no tentacles, unlike its living counterpart.

**A research student stands in the back with two parts of the smaller initial version of the robot jellyfish, which was named robojelly. This version was no bigger than a human hand and worked in a tethered fashion.**

The ultimate robot jellyfish that scientists and the Navy hope to produce from this research will be used to study sea life, ocean currents, and ocean bottoms, as well as to recon oil spills and conduct ocean-based military surveillance. (Since the Naval Undersea Warfare Center funded the robotic research, it's likely Cyro will have ample applications in national defense.)

Don't forget, meeting up with a real jellyfish can be a

shocking experience; however, there is no word that this kind of defensive or offensive mechanism will be part of any future such robots.

## The First Discovery of Many to Come

Cyro has already enlightened researchers with an interesting new piece of data: Larger jellyfish swim and move through the water more efficiently than smaller jellyfish do. Cyro uses its eight electric motor powered appendages to move through the water by pushing downward. This closes its bell similar to closing an umbrella, which creates a downward propulsive thrust in the water.

Cyro operates autonomously, and currently has a battery life of just four hours. This capacity must be greatly improved on, however, since scientists will want to be able to study ocean life and activity, and collect any data for weeks at a time before the rechargeable nickel metal hydride battery must be replenished.

While the researchers have studied how to use an interaction between the platinum in the robot's skin and the hydrogen in the water to produce power for the robot, this analysis is still in progress.

## The Life of Cyro

Using electric field based technology from UCLA researchers, Cyro senses the world around it and communicates back to its creators wirelessly. Other schools involved in the project include Stanford, Providence College, and the University of Texas at Dallas. So far, the project has received $5M in funding.

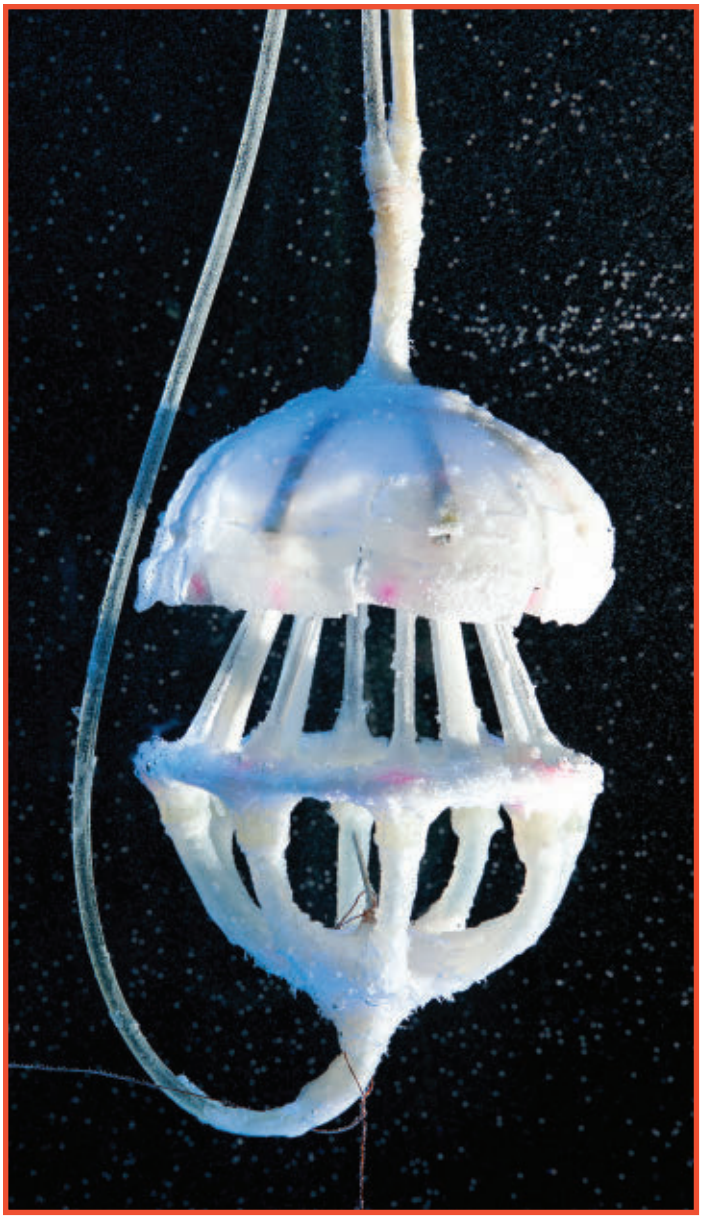
The jellyfish was selected for robotic duplication because of its presence in both salt and fresh water habitats at multiple depths, which means that neither people nor sea life would be surprised to see it. This makes it a lot easier to convince someone (or whatever) that Cyro is the real McCoy.

## Modeling Robots After Life

It is growing increasingly more common for roboticists to model their robots after people, animals, and plant life that have traits or characteristics that can transfer well and be of use in robots to control and/or solve certain problems. As a creature, jellyfish have a very low metabolic rate. So, resultantly, require very little energy. Since batteries and power supplies in general are already challenges in robots, modeling this "low power" trait of the jellyfish successfully could ultimately be a huge boon to robotics — especially if it can be transferred to other robotics applications.

Like real jellyfish, Cyro does not have a backbone. Rather, it uses a diffused nerve net to simultaneously swim, sense, and examine data. The robot can endure a broad range of temperatures, so should be able to handle the many different temperatures of the ocean. Researchers can fit Cyro with a variety of caps or outer skins of various sizes and colors to make each one look unique, as well as more lifelike in appearance.

Cyro's removable skin membrane consists of a thick yet flexible silicone shell. This enables the robot to travel in a realistic manner, so that it looks like a giant jellyfish traversing the water with its skin moving out and then



**The hand-sized robojelly — the first prototype of the robot jellyfish. Its tether and other parts are visible. This smaller model (together with the larger Cyro) enabled the researchers to learn that larger jellyfish move more efficiently than smaller ones do.**

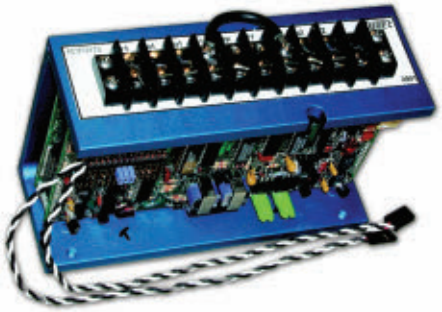
Here a researcher holds half of the bell of the smaller robojelly, allowing a view into its inner workings.

thrusting downward to create movement. The membrane fits over the umbrella-like frame of the mechanics and electronics of the robot that actually do the swimming and perform its other functions.

Ultimately, participants want the robot project to lead to a Cyro version that can carry large payloads and travel to even greater depths in the ocean.

Additional goals include decreasing power consumption, increasing the time it spends under water, and making the robot swim more proficiently. As with any similar project, researchers hope to better understand the robot's living counterpart.

STEER WINNING ROBOTS WITHOUT SERVOS!



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## Resources

Video of Virginia Tech's autonomous robot jellyfish, Cyro
**http://vimeo.com/62880818**

Video report of Cyro by HLN
**www.hlntv.com/video/2013/05/08/robotic-jellyfish-virginia-tech-surveillance**

Coverage of the smaller robojelly on the Virginia Tech site (with video)
**www.vtnews.vt.edu/articles/2012/05/052912-engineering-robojelly.html**

## Named at Birth Using a Common Scientific Naming Convention

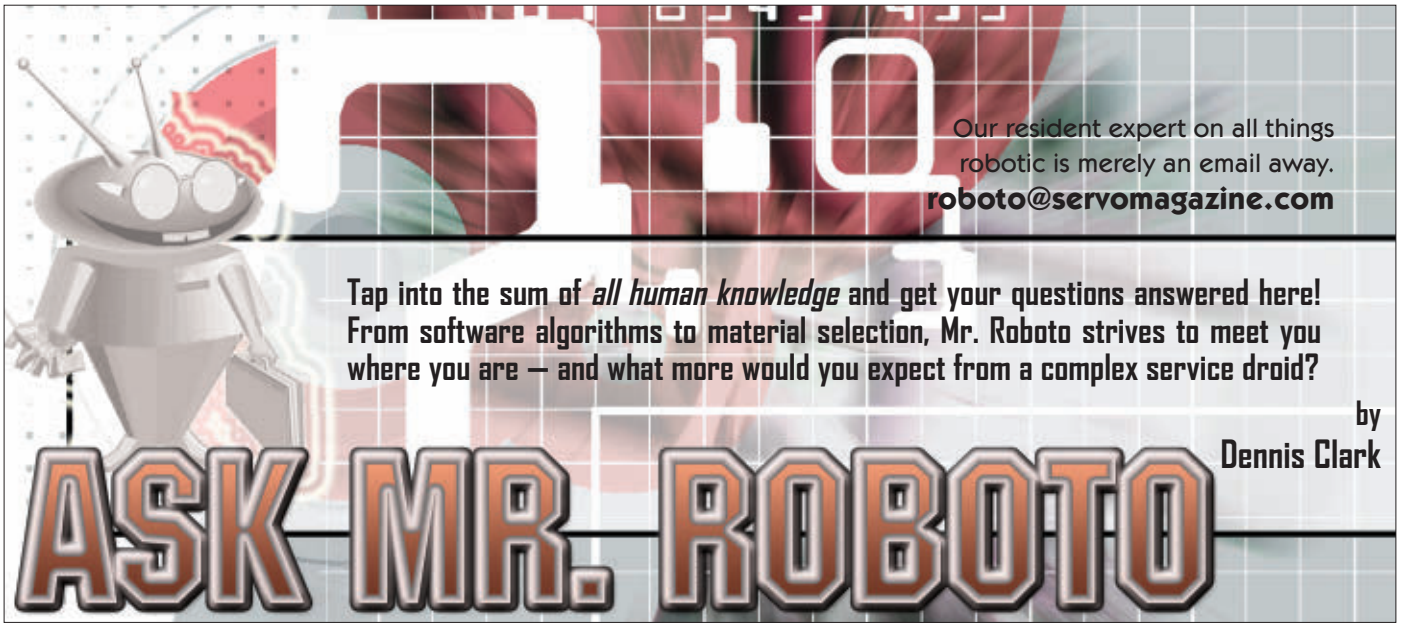
Cyro's name comes from joining the first two letters of the real "lion's mane" jellyfish's Latin species name — *Cyanea capillata* —with the first two letters of the word robot, which forms cy-ro, or Cyro. This follows the common scientific naming convention of joining parts of terms for known entities or qualities in order to name a newly discovered or created thing.

## The Lonely Cyro Has No Date

Neither the Cyro researchers nor the Navy have published a deployment date for a production Cyro robot jellyfish. Still, Virginia Tech researchers Shashank Priya, Alex Villanueva, Kenneth Marut, and Tyler Michael will forge on, nurturing their creation into an investigative workhorse jellyfish for the US Navy.

Virginia Tech builds the robot jellyfish bodies based on fluid mechanics research. The school also develops the robot's control systems and is attempting to increase the artificial intelligence for the robot, perhaps making it more multitasking as with the real jellyfish. The robot's builders have encased the control mechanism in the center of the robot; it is visible through a sheet of transparent material at the top and center of the robot's frame.

Virginia Tech's Durham Hall for engineering is already at work on the next prototype which will be closer to the production model at Professor Shashank Priya's Center for Energy Harvesting Materials and Systems. While the Navy has its applications, the researchers at Virginia Tech are seeking to increase a body of knowledge by modeling an intellectual picture of how the jellyfish's locomotive capabilities improve as it increases in size. **SV**




I hope that you all have been busy building and debugging robots. In between a gazillion other projects, I've been working on upgrading my "roboting" skills by building walker bots. This is way more difficult than building roller bots. Rolling robots don't have balance issues or need really precise coordination to move. Calculating a turn angle is about a hundred times easier than making the legs of a biped work in concert, without high velocity attempts to fling itself at the ground!

Last month, I wrote about interfacing Robotis Dynamixel AX12 servos to the Digilent MX3cK MPIDE-based (Arduino-like) microcontroller. This is a fast board, but it is also a 3.3V board. So, we had to translate voltage levels, as well as create a half-duplex bus circuit to talk to the servos. Well, that worked pretty well, but I found some issues with my code when I started working with various other servos. So, this month, I put together (perhaps) my last rolling robot chassis using these amazing devices.

Recall the original question from last month ... *I want to control my Bioloid Dynamixel servos with a Digilent UNO32 or Max32 controller on a new robot. How can I talk to these servos with MPIDE? I read that it is a totally different type of servo than a hobby servo. Can you help me?*

Our saga continues...

The circuit that I gave last month works fine. However, I found that I always have an extra 0xFF character in the beginning of the AX12 response packet. I suspect that flipping from transmit to receive is generating a false start bit which sees all '1's clocked into the UART, which looks like a 0xFF. To keep this from becoming really odd, I re-worked my command driver code as shown in **Listing 1**. This has shown itself to be very robust and never gives flaky response packets (well, it hasn't so far anyway!).

I've commented the section where *SendCmd()* switches between transmitting and receiving to show what I was thinking. I read the Microchip PIC32 UART documentation and found a bit in the U2MODE register that allows us to turn the UART off. So, I turn the UART off, flip the hardware to receive mode, and then flush the UART receive register before turning the UART back on. The result is that we only get the data being sent by the servo now.

Notice the *#ifdef* at the top and bottom of the function; sometimes we like to see exactly what is being sent and received. If — at the top of the program — we *#define _DEBUG_ flag*, we will get this debug output on the MPIDE terminal at 115200 baud, as *setup()* lays out. This turned out to be useful when I started working with a new AX12A servo I got to make my rolling robot.

## Communication Woes

When I got my new AX12A servo, I immediately tried to talk to it with my code — only to find that my code could not really talk to it. There is a function in the DynamixelDriver .pde program that looks for servos on the bus. **Listing 2** shows the obvious bits of what this "servo hunt" function does.

My output was showing that it found my original servo at address 19 and another one at address 2. However, nothing would answer on address 2! Also, I saw that I was only getting one 0xFF flag byte in my servo response. Hmm. What was going on here?

Well, sometimes a specification sheet can only take you so far, then you need to seek help. Help for me came in the form of a piece of hardware and software that Robotis sells, and luckily I had it — the

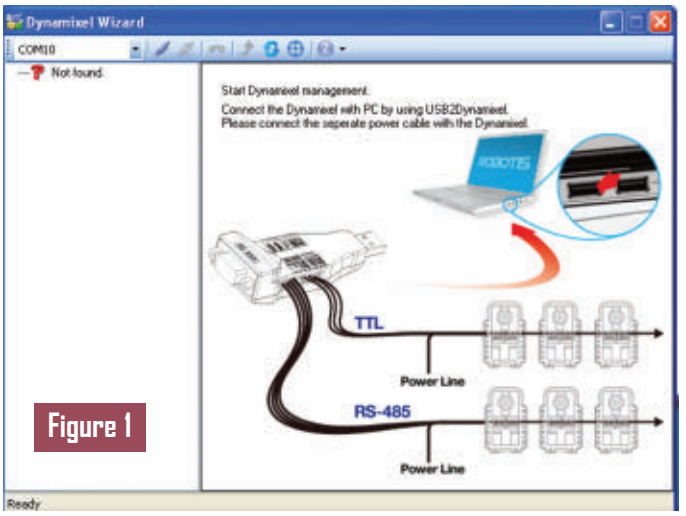


Figure 1

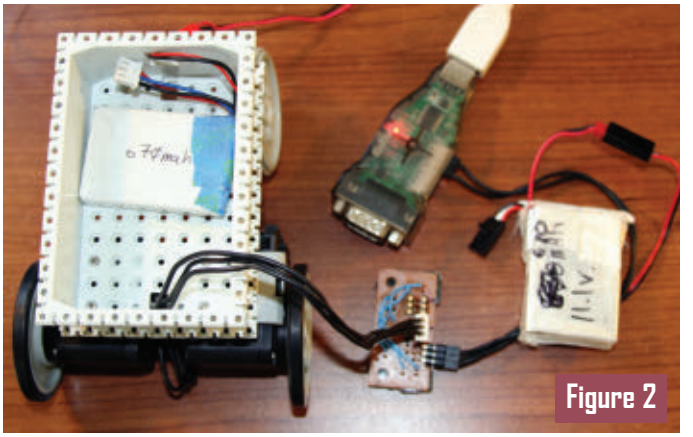


Figure 2

USB2Dynamixel device and the Dynamixel Wizard program.

**Figure 1** shows the screen that you get when you first start this (Windows only) program. It very carefully tells you that the USB device cannot power the AX12 servo; you need to provide external power. This isn't too bad. **Figure 2** shows my setup where I hacked a servo cable to splice in a battery on the ground and V+ line to the servo. The ground line also goes to the USB2Dynamixel, and the signal line goes between the AX12 bus and the USB2Dynamixel. I created a small jumper board that allows me to plug all of the cables together without having to pull too many cables apart.

Whenever you connect a device to USB on your computer and that device has its own power supply, you need to be sure that the grounds are common and correctly connected or POOF! There goes the USB port or even your computer! This is why I

## Listing 1: New SendCmd()

```
uint8_t SendCmd  (uint8_t *cmd, uint8_t cLen,
                  uint8_t *stat, uint8_t *sLen)
/*
*   Send Dynamixel command, return status in the
*   cmd arrayINPUT: cmd[] to send , cLen is
*   length of command OUPUT: stat[] status
*   returned , sLen is length of status
*
*   RETURNS: non-zero if an error
*/
{
  uint8_t n = 0;
  uint32_t t;

#ifdef _DEBUG_
  Serial.print(cmd[2],DEC);Serial.print
  (":CMD= ");
PrintStatus(cmd, cLen);
#endif

  digitalWrite(nTxU2, LOW);
       // writing out cmd
  Serial1.write(cmd, cLen);

  while(U2STAbits.TRMT == 0);
       // Wait for all bytes to go out
  digitalWrite(U2MODEbits.ON, 0);
       // Turn UART off
  digitalWrite(nTxU2, HIGH);
       // switch to listen
  Serial1.read();
       // switch generates false start bit
  digitalWrite(U2MODEbits.ON,1);
       // Turn UART back on

  t = micros() + 500;
       // This timer not very accurate
  while (micros() < t)
       // wait for reception to start
  {
    if (Serial1.available())
    {
      stat[0] = Serial1.read();
      if (stat[0] = 0xFF)
      {
        n++;
        break;
      }
    }
  }

  if (n == 0)
       // never got start byte
  {
    return(0xFF);
       // error flag
    *sLen = 0;
  }

  t = micros() + 500;
  while(micros() < t)
       // Get the rest of the packet
  {
       while(Serial1.available() > 0)
       {
         stat[n++] = Serial1.read();
       }
  }
  *sLen = n;
       // what we read back, always seem to get
       // one extra...

#ifdef _DEBUG_
  Serial.print(cmd[2],DEC);Serial.print
  (":Stat= ");
  PrintStatus(stat, *sLen);
#endif

  return(stat[4]);
       // return the error byte
}
```

## Listing 2: LookBus().

```
uint8_t CmdPing(uint8_t sid, uint8_t *stat, uint8_t *statLen)
/*
*  Look for a servo at a specific address.
*  return error status
*/
{
 uint8_t cmd[6], cmdLen;
 uint8_t err;

 cmd[0] = 0xFF;
 cmd[1] = 0xFF;
 cmd[2] = sid;
 cmd[3] = 0x02;
 cmd[4] = DM_PING;
 cmd[5] = GetCSUM(cmd,3);  // get checksum

 cmdLen = 6;
 err = SendCmd(cmd, cmdLen, stat, statLen);
 return(err);
}

void LookBus(uint8_t limit)
/*
* Scan the bus from address 0 to 'limit' to find all servos there.
*/
{
 uint8_t n;
 uint8_t stat[6],statLen;

 for (n=0; n<=limit; n++)
 {
  err = CmdPing(n, stat, &statLen);
  if (err != 0xFF)
  {
   Serial.print("Stat: ");Serial.print(n,DEC);Serial.print("=
   ");PrintStatus(stat, statLen);
  }
  delay(100);
 }
}
```

always have another USB hub between my projects and my computer — so that I can blow up a cheap USB hub instead of something more costly.

I also prefer to use a battery rather than an external power supply. This way, I don't have to worry about isolating power supplies whose grounds may be "floating" and therefore at an unknown voltage level. Batteries are safer.

Anyway, after I connected my AX12 servo bus to the USB2Dynamixel and had it search the bus for servos, I got my list (see **Figure 3**) of servos. In this **screenshot**, you'll see that the servos are at addresses 19 and 20. When I first ran this utility, I actually found the new servo on its default address of 1. I changed it to address 20 later on. Huh? I thought that my code saw this servo on address 2. What gives?

**Figure 4** shows part of the Wizard's query of the servo and the source of my problem. Control Register 5 "Return Delay Time" was set to 250 µs on this servo. (Yes, I know. My **screenshot** shows zero. I was fiddling with it. Not only that, I eventually set both servos to respond in 50 µs, just to give me some breathing room in my code.)

In the *SendCmd()* function in **Listing 1**, you'll see that I wait 500 µs before timing out on a servo response. The Arduino documentation says that the *micros()* ticker call isn't that accurate and can be perturbed by other background interrupt code that runs behind the scenes.

What this apparently benign little comment means to me right now is that my new servo took its time (250 µs) to respond, and that response was actually after the 500 µs timeout! I actually saw the response back from the servo when my *LookBus()* function was expecting to see a response from servo 2! Ouch! Oh well, I was warned.

Everything works fine with the DynamixelDriver code with the Return Delay Time set to 50 µs. Another nifty thing that the Dynamixel Wizard code does is continually read the AX12 servo. So, if you are "posing" a walking robot, you can move all of its joints where you want them, look to see what their actual positions are, and then record them with this tool. Very handy!

Now that I have my communications issues ironed out, it's

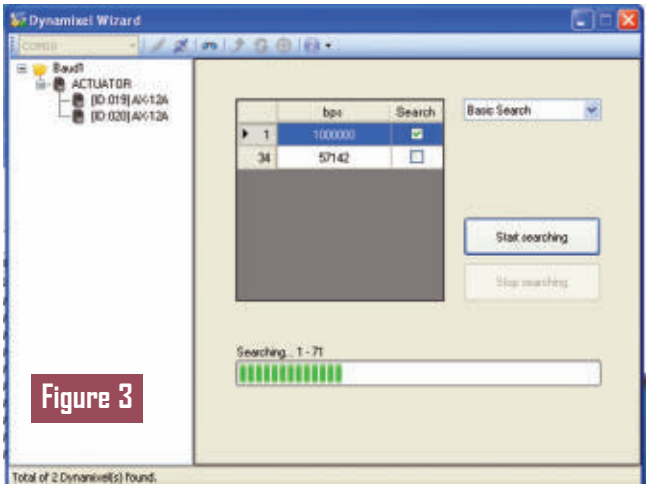


Figure 3

Figure 4

time to move on to making my robot move around.

## Driver Upgrades are a Good Thing

While my DynamixelDriver code in June worked, it was kind of clumsy to use. Download the revised DynamixelDriverJuly.zip code and have a look around. I made the *CmdReadControl()* and *CmdWriteControl()* functions more generic. This way, calling routines only need to set up the parameter values in a small array, and then pass the *enum DMControls_e* entry to these functions. The functions then will use the two arrays *dc[]* and *db[]* to get the control addresses and number of parameters. With this re-write, other functions like *CmdMove()* are easier to use (refer to **Listing 3**).

To fully understand what is going on here, you need to read the Dynamixel AX12 user's manual under the section 3.4 on page 12: Control Table. This tells you all the control table addresses and parameter bytes to write or read back. All data is sent "little endian," which means the lowest byte of a multi-byte parameter is sent first. Read some of the commands to see how the two bytes of a 16-bit parameter are separated and sent (hint: >>8).

The AX12 defaults to servo mode when it is shipped. If you set the *CCWAngleLimit* (see the table in section 3.4 of the manual) to zero, you effectively have a continuously rotating motor instead of a servo. Set this value back to 1023, and it becomes a servo again. When the servo is a motor, the *MovingSpeed* registers effectively become *GoalSpeed* registers whose format becomes

**Listing 3: CmdMove() is easier to write and use.**

```
uint8_t CmdMove(uint8_t sid, uint16_t val)
/*
*   move the servo motor to a position.
*   sid = the servo ID
*   val = the position
*
*   Returns error status
*/
{
   uint8_t data[2];
   uint8_t err;

   data[0] = (uint8_t)val;
   data[1] = (uint8_t)(val >>8);
   err = CmdWriteControl(sid, data, dmPosition);
   return(err);
}
```

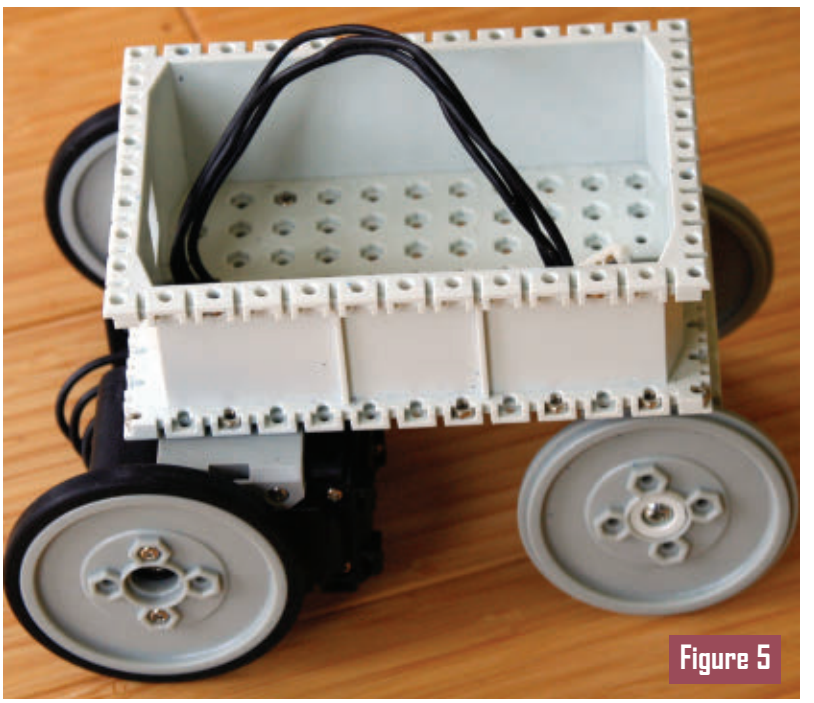


Figure 5

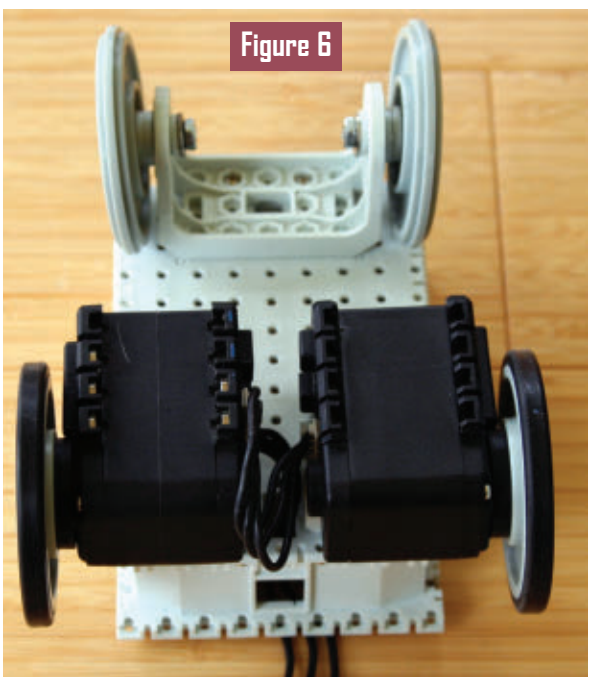


Figure 6

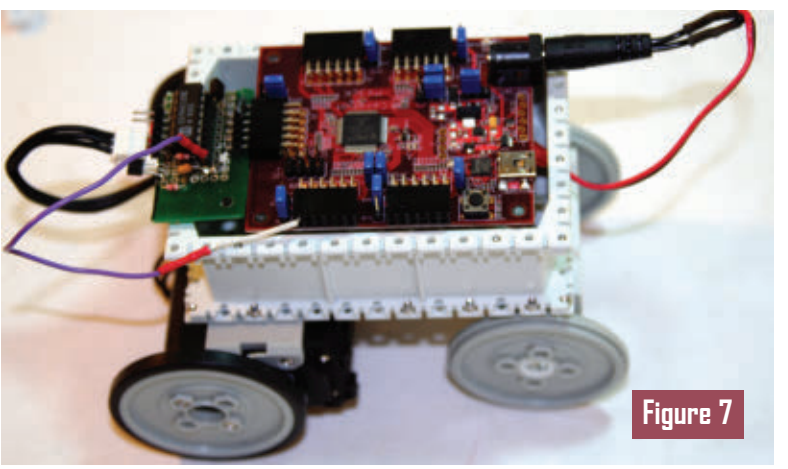
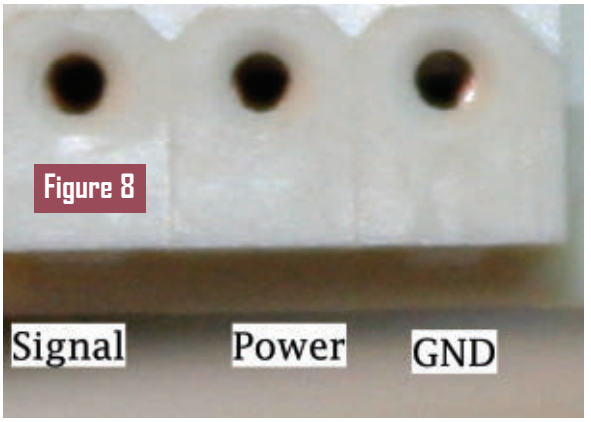


Figure 7

| BIT | 15-11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Value | 0 | Direction | Speed Value | | | | | | | | | |

**TABLE 1:** Direction bit: 0 is CCW direction; 1 is CW direction.




what you see in **Table 1**. The new functions *CmdTurnMode()* and *CmdRoll()* put the AX12 into continuous turn mode, and set the speed and direction of the servo, respectively (refer to **Listing 4**).

Now, we can make the servos act like motors whose direction, speed, and lots of other things — like acceleration curves and torque — can be set. (You did look at all of the control table addresses, didn't you?)

## A Robot Needs to Move

To see how I created my testbed robot, look at **Figures 5**, **6**, and **7**. This isn't my most elegant model, but I could make it from parts in my Bioloid Comprehensive kit and it works ... mostly. There are two LiPo batteries in the main body, an 11.1V battery for the servos, and a 7.4V battery for the MX3cK. After we program our new sketch into the board, we can unplug and go.

**IMPORTANT TIP:** If you are using a Mac on OSX, then make sure that you close your MPIDE serial port terminal window before you disconnect the USB connector from the MX3cK. If you don't, you will crash your Mac, hard!

The code that is supplied in the zip file makes the robot define a four sided geometrical shape — I won't glorify it by calling it a square; it just moves the robot around.

The MX3cK has lots of analog inputs, digital I/O, SPI, and I²C ports to use for sensors to do something sensible. With 128 KB of Flash, 8 KB of RAM, and running at 80 MHz, it has lots of potential!

## A Clarification, and a Big Sigh of Relief!

Last month, I gave you the pinout of the AX12 servo cable. Well, I actually gave you the pinout of the connector you plug the cable into. **Figure 8** shows the pinout from the point of view of the cable. Fortunately, the AX12 is a properly built device and tolerates being plugged in backwards just fine. (I know this from lots of experience.)

Using the AX12 won't win you any speed races at its 114 RPM, but hey, it works! (Although, this speed is pretty snappy when moving joints in a robot arm or walker. Hmm ...) As usual, feel free to hack away at the code presented here and let me know what you do with *your* toys.

Well, that wraps up another session with Mr. Roboto. Keep sending those questions and I'll do my best to answer them! You can contact me at roboto@servomagazine.com. **SV**

### Listing 4: Making the wheels go 'round.

```
uint8_t CmdTurnMode(uint8_t lSid, uint8_t rSid,
uint16_t mode)
/*
*  Make these two servos continuous rotation.
*  mode: 0 = cont. rotation, 1023 = servo
*  Returns error status
*/
{
  uint8_t data[2];
  uint8_t err;

  data[0] = (uint8_t)(mode);
  data[1] = (uint8_t)(mode >>8);

  err  =
CmdWriteControl(lSid,data,dmCCWAngleLimit);
  err |=
CmdWriteControl(rSid,data,dmCCWAngleLimit);

  return(err);
}

uint8_t CmdRoll(uint8_t lSid, uint8_t lDir,
uint16_t lSpd,
                uint8_t rSid, uint8_t rDir,
                uint16_t rSpd)
/*
* Make robot go in a certain direction:
* [l/r]Sid = left/right servo ID
* [l/r]Dir = 0 CCW, 1 CW
* [l/r]Spd = speed 0-1023
* Returns error status
*/
{
  uint8_t data[2];
  uint8_t err;

  /*
  * Servos reversion direction when mirrored,
  * so reverse the direction bit on the right
  * side servo.
  */
  rDir = ~rDir&0x01;

  /*
  * direction and speed are in a 16 bit data
  * word: 15-11: 00000 | 10: [0=CCW, 1=CW] |
  * 9-0: speed value (0-1023)
  */
  data[0] = (uint8_t)lSpd;
  data[1] = (uint8_t)(4*lDir) | (uint8_t)((lSpd
  >>8)&0xFC);
  err  = CmdWriteControl(lSid,data,dmMovSpeed);

  data[0] = (uint8_t)rSpd;
  data[1] = (uint8_t)(4*rDir) | (uint8_t)((rSpd
  >>8)&0xFC);
  err |= CmdWriteControl(rSid,data,dmMovSpeed);

  return(err);
}
```

# EVENTS

ROBOTS.NET

Know of any robot competitions I've missed? Is your local school or robot group planning a contest? Send an email to steve@ncc.com and tell me about it. Be sure to include the date and location of your contest. If you have a website with contest info, send along the URL as well, so we can tell everyone else about it.

For last-minute updates and changes, you can always find the most recent version of the Robot Competition FAQ at Robots.net: **http://robots.net/rcfaq.html**.

**— R. Steven Rainwater**

## JULY

**6** **RoboBombeiro**
*San Miguel Pavilion, Guarda, Portugal*
Fire fighting robot competition originally based on the Trinity College rules. Robots start from an arbitrary location within a house, must avoid a dog, while searching for and extinguishing a fire.
**http://robobombeiro.ipg.pt**

**6-10** **Botball National Tournament**
*Norman, OK*
Student teams build autonomous robots that compete in a game involving the movement of balls. See the website for details.
**www.botball.com**

**14-18** **AAAI Mobile Robot Competition**
*Bellevue, WA*
Every year the AAAI Conference includes a different type of competitive event for autonomous robots. Check the conference for more details.
**www.aaai.org/Conferences/conferences.php**

**21-24** **ASABE Robotics Competition**
*Kansas City, MO*
Student teams build an autonomous robot to compete in an agricultural themed contest at the annual ASABE Conference.
**www.asabemeetings.org**

**22-26** **K*bot World Championships**
*Las Vegas, NV*
Student robots compete in a variety of contests categories including two wheel autonomous K*Bots, four wheel autonomous K*Bots, Cyber K*Bot remote controlled, and the motorless K*Bot division. Bring plenty of asterisks.
**www.kbotworld.com**

**22-28** **International RoboSub Competition**
*SSC Pacific TRANSDEC San Diego, CA*
University student teams build autonomous underwater vehicles that must complete an underwater course with various obstacles and goals.
**www.robosub.org**

**26-27** **International Autonomous Robot Racing Competition**
*University of Waterloo, Waterloo, Ontario, Canada*
Student teams build high-speed autonomous racing robots that must avoid collisions with each other and fixed obstacles, while observing traffic control rules and maintaining localization.
**http://robotracing.wordpress.com**

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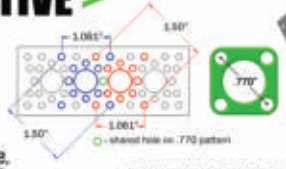


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# NEW PRODUCTS

## New GoPro Mounting Kits

Brand new from ServoCity is a simple, lightweight, and versatile mounting kit for GoPro cameras. The aluminum hub plate has four 6-32 tapped holes for mounting various attachments. It also incorporates the 0.770" hub pattern that is found throughout ServoCity's product line. The mount is compatible with Actobotics™ components, making it simple to integrate a GoPro into a robot, camera slider, or other Actobotics structure. Pair this mount with ServoBlocks™ for a pan or tilt mechanism. The rubber ring provides a no-slip grip and is easy to attach and detach as needed. The mount can be used in a hanging, upright, or sideways position. The kit includes a plastic face plate, rubber ring, aluminum hub plate, and two 6-32 pan head screws (camera not included). There are two models available; #585516 is designed for use with the GoPro Hero and Hero 2; the #595618 is made for the new GoPro Hero 3. Both models are $9.99.

## New Drive Wheel Adaptor

ServoCity is also now offering a way to mount popular roller-blade and scooter wheels to motor hubs, gears, pulleys, sprockets, and other like pattern components. The Actobotics drive adaptor A (595630) replaces wheel ball bearings with a .770" hub pattern adaptor, incorporating both 6-32 tapped holes and #6 thru holes. The 1/4-20 bolt joins the two parts for a slip resistant connection. This adaptor provides a simple solution for integrating low friction wheels into robotic platforms or camera dollies. They're priced at $5.99 each.

For further information, please contact:

**ServoCity** Website: **www.servocity.com**

Is your product innovative, less expensive, more functional, or just plain cool? If you have a new product that you would like us to run in our *New Products* section, please email a short description (300-500 words) and a photo of your product to:

**newproducts@servomagazine.com**

## Online Master's Program in Robotics Engineering

Worcester Polytechnic Institute (WPI) announced that it has launched an online, part-time master's program in Robotics Engineering, making it among the first colleges in the country to offer such a program.

The program will be primarily focused toward professionals such as engineers and computer scientists who are currently working in the field of robotics, according to Pamela Strombom Shelley, an associate director in WPI's Corporate and Professional Education office.

The program seeks to impart students with a solid understanding of the fundamentals of computer science, electrical and computer engineering, mathematics, and mechanical engineering that make up robotic systems; an awareness of the management and systems contexts within which robotic systems are engineered; and advanced knowledge in selected areas of robotics, culminating in a capstone project experience.

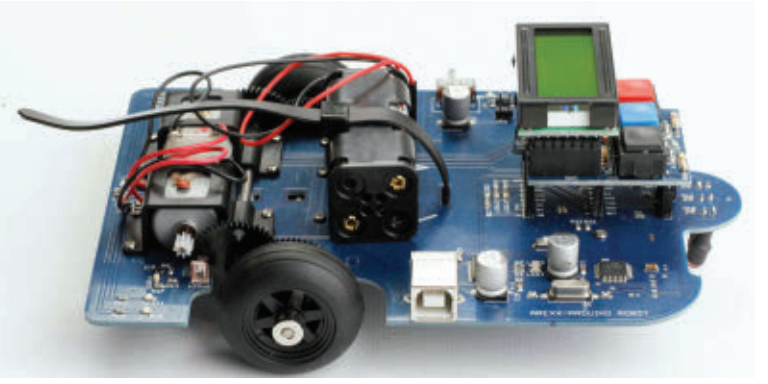
The first course — which will be offered in the fall of this year — is called "Foundations of Robotics," and will focus on mathematical foundations and principles of processing sensor information in robotic systems. Topics include an introduction to probabilistic concepts related to sensors, sensor signal processing, multisensor control systems, and optimal estimation.

Shelley noted that both online and on-campus students in the program will take the same courses and have their assignments due at the same time. Online students will view lectures on their computers and will have access to teachers via email, discussion boards, and telephone. Online classes will have no more than 25 students.

For further information, please contact:

**Worcester Polytechnic Institute**
Website: **http://cpe.wpi.edu/online/robotics-master.html**

## New Arduino-Based Robot

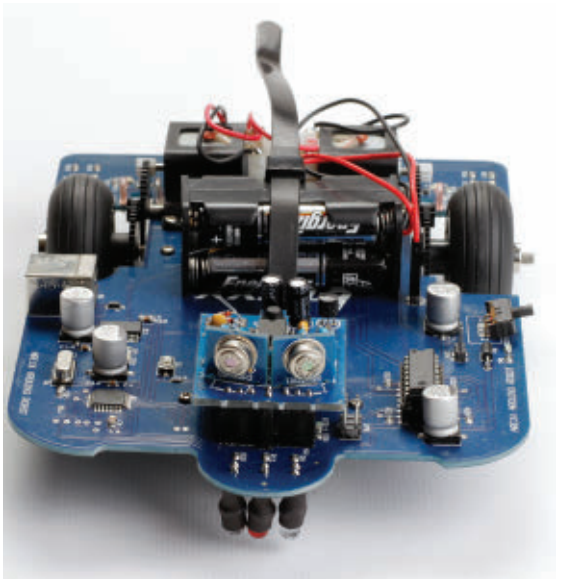


Global Specialties introduces their new AAR Arduino robot which is a small autonomous mobile robot that is ideal for those new to the robotics world, as well as for experienced Arduino fans.

Designed in the Arduino open source prototyping platform, the AAR is simple to program and run. With many expansion kits available, creativity may be the only limit to where this Arduino robot can go. The AAR comes with a comprehensive CD which includes all the ncessary software to write, compile, and upload programs to the robot. There are also several example programs supplied. It is priced at $79.

AAR Arduino robot features include:

- ATmega328P, eight-bit AVR-RISC processor with 16 MHz clock.
- Includes firmware and hardware selftest.
- Delivered fully assembled (no soldering needed).
- CD with software, manual, and many extras.
- Arduino open source software.
- Onboard odometer sensor on both wheels.
- Line tracker sensor.
- USB interface programming.
- Expansion kits available.
- $I^2C$ bus.
- Two independently controlled 3V DC motors.
- 14 digital I/Os on the processor (nine free).
- Eight analog input lines (two free).
- ISP connector for bootloader programming.
- Wireless control possible with optional Bluetooth and 433 MHz RF.
- One year warranty.



For further information, please contact:

**Global Specialties**
Website: **www.globalspecialties.com**

## Flexible Resolution Oscilloscopes

Pico Technology is now utilizing reconfigurable ADC technology to offer a choice of resolutions from eight to 16 bits in a single product.

Most digital oscilloscopes gain their high sampling rates by interleaving multiple eight-bit ADCs. Despite careful design, the interleaving process introduces errors that can make the dynamic performance worse than the performance of the individual ADC cores.

The new PicoScope 5000 Series scopes have a significantly different architecture in which multiple high resolution ADCs can be applied to the input channels in different series and parallel combinations to boost either the sampling rate or the resolution.

In series mode, the ADCs are interleaved to provide 1 GS/s at eight bits. Interleaving reduces the performance of the ADCs, but the result (60 dB SFDR) is still better than oscilloscopes that interleave eight-bit ADCs. This mode can also provide 500 MS/s at 12-bit resolution.

In parallel mode, multiple ADCs are sampled in phase on each channel to increase the resolution and dynamic performance. Resolution is increased to 14 bits at 125 MS/s per channel (70 dB SFDR). If only two channels are required, then resolution can be increased to 15 bits, and in single channel mode all the ADCs are combined to give a 16-bit mode at 62.5 MS/s.

Careful attention was required to support the high resolution modes (with low noise, low distortion, and bandwidth flatness), while maintaining the bandwidth, slew rate, and pulse response necessary for the faster eight-bit mode.

As well as flexible resolution, these oscilloscopes have ultra-deep memory buffers of up to 512 MS to allow long captures at high sampling rates. Also included as standard are advanced software features such as serial decoding, mask limit testing, and segmented memory.

The PicoScope flexible resolution oscilloscopes are priced from US$1,153/ 846 for the two-channel 60 MHz model with built-in function generator to US$2,803/ 2056 for a four-channel 200 MHz model with built-in AWG. Prices include a set of matched probes, all necessary software, and a five year warranty.

For further information, please contact:

**Pico Technology** Website: **www.picotech.com**

## GPS Receiver With Touch Screen

This cost-effective, intelligent LCD touch screen display module kit offered from Parallax adds interactive, multimedia functionality to microcontroller projects. The module (uLCD-32PTU) is from 4D Systems – a leading developer of LCD screen technology. Implementation of the screen into a project is made easy with with 4D System's comprehensive "Workshop4" IDE tool suite. The IDE tool helps users set up graphical interfaces that can be used with a simple serial connection to a microcontroller.

The uLCD-32PTU delivers colors suitable for animations, slideshows, and other multimedia presentations. The module has an SD card connector for the included 2 GB microSD card. The expandable memory space can be used for multimedia files, including movie clips or sound files.

The uLCD-32PTU can be programmed in its native 4DGL language (similar to C), or it can be configured as a serial slave.

The retail price is $106.

For further information, please contact:

**Parallax** Website: **www.parallax.com**

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# bots IN BRIEF

## LOCKER BOT OF SORTS ...

Courtesy of GILLIS BENEDICT/DAILY PRESS & ARGUS.

Muscular dystrophy robbed high school student Nick Torrance of his ability to walk, open his locker, and do other everyday tasks many take for granted.

Starting this year, the Pinckney Community High School junior took a step toward being just like any other student. He can open his own locker.

Two Pinckney seniors — Micah Stuhldreher and Wyatt Smrcka — used their robotics ingenuity and created an automatic locker opener.

Sitting in his wheelchair, Torrance slightly moves his hand over a sensor and his locker pops open. He moves his hand again, and the locker closes. Torrance, who is shy, said he likes the locker opener.

"The device is amazing," Amy Uphouse said. She's an occupational therapist for the Livingston Educational Service Agency and helps Torrance become more independent.

When she first thought about this idea, Uphouse figured there must be a device to do this, and she searched the Internet for one but couldn't find it.

She asked Pinckney Community High School robotics teacher, Sean Hickman if he thought this could be a student project. "Absolutely," was his response, and he knew exactly who should take it on; two students who took first place in the SkillsUSA national robotics competition in 2012 and are returning to the national competition this year.

"It's good to see it works," Stuhldreher said as Torrance tested the device. Stuhldreher and Smrcka have been working on the device all year, improving it through trial and error.

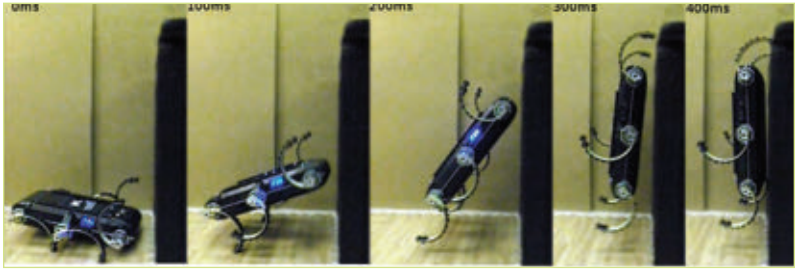
"Just the fact that he can be able to do it on his own," Smrcka said makes him feel good.

The two students didn't know much about the task at first; Hickman told them he had a "project" for them.

They were told to tear off a locker door and figure out a way to open and close it. They originally installed a relay inside the locker, but it took up too much space, so they switched to a computer.

They first used a key fob to activate the robotic device which opened the locker, but they said Torrance wasn't strong enough to press the button. So, they switched to a sensor.

The two students won a $1,500 minigrant from the Society of American Military Engineers so other devices can be made. Both plan to pursue robotics as a career.




## JUMPING FOR JOY

University of Pennsylvania researchers have taught their RHex legged robot to jump. The results are pretty darn amazing. RHex is learning to cross gaps by employing a series of jumps. If that series of jumps is extended, it provides a quick transition method from a stationary position to a running gait.

Jumping is also good if you've got a sensor that you need to be at a certain height to use, or if you need to flip yourself over.

Note that RHex is not a small robot. The UPenn researchers are using their X-RHex Light, or XRL, which weighs 6.7 kilograms (14.8 pounds) and has a body length of 51 centimeters (20 inches). The robot has six compliant C-shaped legs — each with a diameter of 17.5 centimeters (6.9 inches) — that are independently actuated by Maxon 50-W brushless motors. As far as what's next, the researchers are experimenting with "a broader range of dynamical transitions, particularly ones exploiting compliance, including the entirely novel prospect of using the leg springs in extension introduced here."

## A ROBOHAND FOR LIAM

When Richard Van As — a woodworker in South Africa — decided to make a set of mechanical fingers, it wasn't just for fun. He'd lost four of the fingers on his right hand in an unfortunate work accident. For a carpenter, a disabled hand is a big professional risk, so Richard decided on the day of the incident that he would use the tools available to him to remedy his situation. Thus was born Robohand — a mechanical 3D printed hand that you can make on a MakerBot Replicator 2 desktop 3D printer.

The Robohand uses a cable system, with the angle of the wrist controlling the tension and causing the fingers to open and close. It's a proven system that's been used on other prosthetic limbs for decades.

Robohand can be adjusted and assembled easily, parts can be replaced if they break, and — best of all — anyone with a 3D printer and some basic off-the-shelf parts can make one.

The Robohand effort started in December 2011 when Van As saw a YouTube video of amateur mechanical engineer Ivan Owen who resides in Bellingham, WA. Owen had built a huge mechanical hand for fun, and the video went viral. However, Van As immediately saw more than novelty value in the device.

Van As contacted Owen, and soon they were collaborating on a prosthetic hand — one which would not cost thousands of dollars like many of them do.

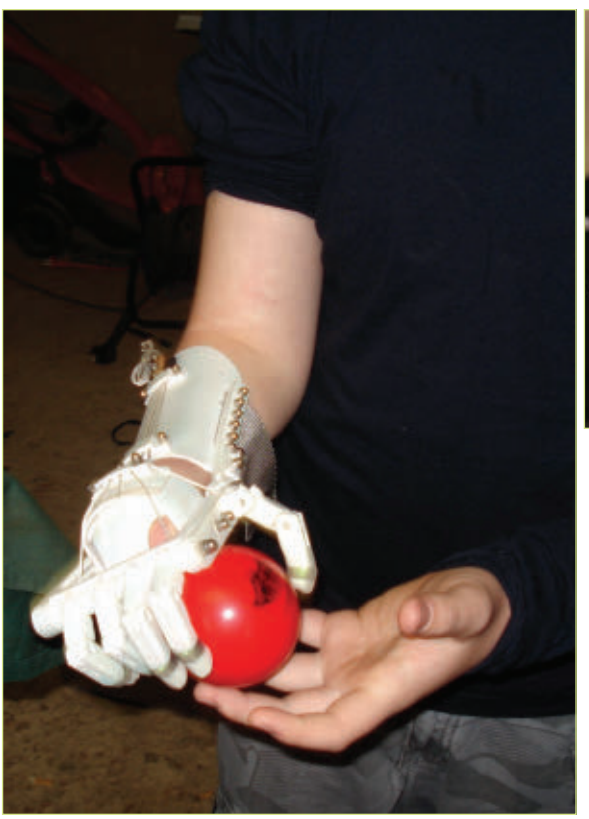
They exchanged designs and comments over email, and last November, decided to join up in Johannesburg to work together in person on a new project: a hand for Liam — a five year-old South African boy born without fingers on his right hand.

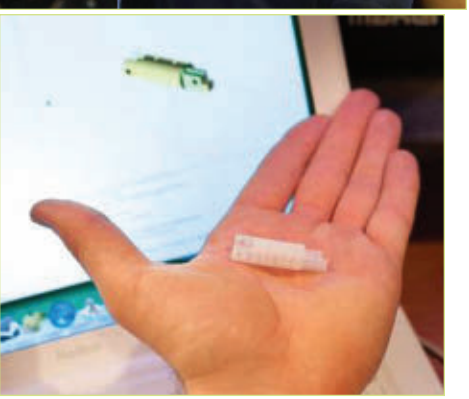
Liam suffers from a birth defect called Amniotic Band Syndrome. Amniotic Band Syndrome is poorly understood, but the effects of it are pretty clear. Children are often born without extremities — especially fingers and toes — when fibrous bands in the womb prevent these parts from developing normally.

It's this condition that caused Liam to be born with missing fingers. The cost of purchasing a traditional prosthesis was far too much for his family, especially since Liam is a fast-growing little boy who would constantly need new prosthesis every few months.

Liam was given a Robohand in January 2013; just days after Richard and Ivan received their MakerBots. He has already been fitted for his second Robohand.

Owen and Van As have put the design up for free on the Internet. It's available at Thingiverse (**www.thingiverse.com/thing:44150**) — a website for sharing printable objects such as this.





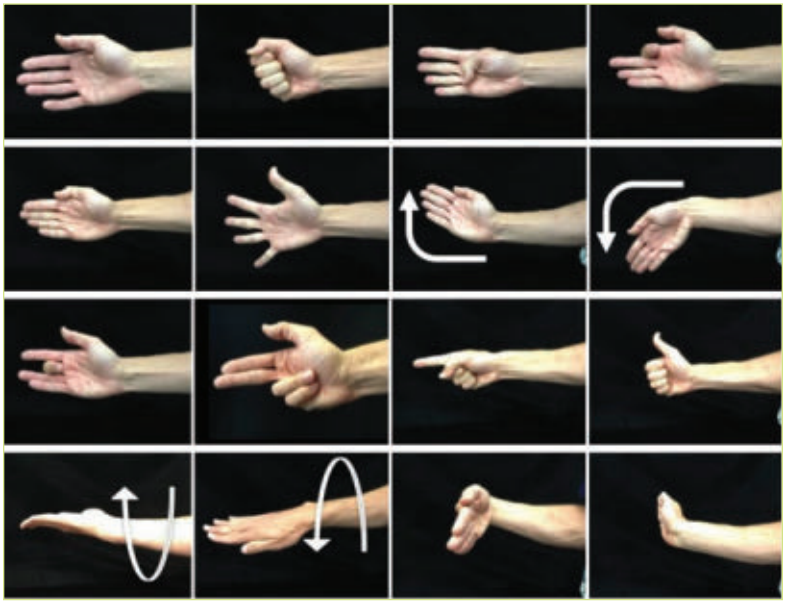
# JPL HAS SOMETHING UP THEIR BIOSLEEVE

No matter how capable you make a robot, its effectiveness is limited by how well you can control it. JPL has been working on a new gesture-based human interface called BioSleeve, which uses a slew of electromyography (EMG) sensors, IMUs, and magnetometers to decode hand and arm gestures, then maps them to an intuitive robot control system.

BioSleeve is a sort of elastic bandage that covers most of your forearm and includes 16 dry contact EMG sensors, plus a pair of inertial measurement units. The sensors can detect movements of the muscles in your arm — which is where the muscles in your hand live — meaning that the BioSleeve can tell when (and how much) you move your arm, wrist, hand, and individual fingers. This enables you to make gestures and have a robot respond to them — much like existing gesture recognition systems, except that since BioSleeve doesn't depend on vision or having your hand in close proximity to a sensor, it's a much easier thing to use for extended periods.

In order to get the robot to go where the user points, it's assumed that the user's approximate shoulder position relative to the robot is known via other sensors. (Shoulder position is generally easy to pick out with something like a Kinect.)

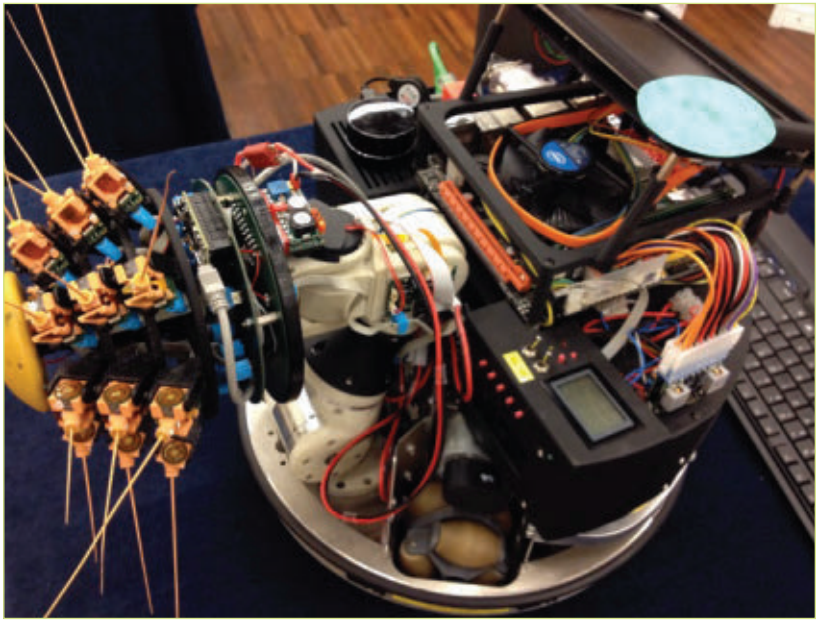
One big advantage of using EMG is that signals are correlated to muscle force. This means that if clenching your fist signals a robot to drive forward, clenching harder will make the robot drive faster. Even with such complicated variations in signal force, you still have several gestures that the BioSleeve can accurately recognize.



The BioSleeve relies on offboard computing to function, so it's a bit bulky to wear. The next generation should be more compact, lighter weight, and fully integrated with embedded computers and batteries. Specifically, the final version will offer the following advantages over existing systems:

- **Ease-of-use:** The BioSleeve will be conveniently embedded into wearable garments; donned and doffed as part of daily clothes. No extra setup time is required for placement of individual electrodes, fine alignment, etc.
- **Free mobility:** There are no external sensors, hand obstructions, or electrode wires imposing constraints on allowable movements.
- **Reliability:** Large dense sensor arrays add redundancy and are more immune from movement artifacts (electrode slippage, etc.), with the potential to dramatically improve decoding reliability.
- **Durability:** Active channel selection and low power consumption per channel enables operation for long periods of time for in-sleeve batteries.
- **Versatility:** The output of the gesture recognition can be mapped into various command libraries for different robotic systems. The system can differentiate which is which with 96.6 percent accuracy. Using a smaller subset of 11 gestures, the accuracy is bumped up to 99.8 percent (or darn close to perfect).

## SHREW WITH ITS SENSES



Robots that make maps tend to be highly reliant on vision of one sort or another, whether it's a camera image or something off the end of the visible spectrum (like a laser scanner). This is to be expected since humans are adapted to use vision, so we understand it pretty well. Plus, we can get a lot of useful information out of a visual image. Animals, on the other hand, take advantage of a much broader suite of senses that are specialized for their environments. If you only come out at night or if you live in a hole, vision is perhaps not the best solution for you.

Shrewbot (which was first introduced in January of last year) is an adorable robot with artificial whiskers modeled after the Etruscan pygmy shrew. Now, Shrewbot can make maps using just tactile feedback from a prodigious set of artificial whiskers.

Shrewbot has been performing what the researchers are calling tSLAM — tactile Simultaneous Localization and Mapping. The robot has an array of 18 individually-actuated whiskers mounted on a three degree-of-freedom neck, attached to an omni-drive mobile platform. Using a combination of wheel odometry and detection by whisking (yes, the behavior really is called whisking), Shrewbot is able to gradually make a tactile map of an area by combining hundreds (or thousands) of whisk contacts that it feels when it encounters walls or other obstacles.

"When the whiskers touch an object, this causes them to vibrate and the vibration pattern is picked up by sensitive cells in the hair follicle at the base of the whisker. These patterns are turned into an electrical signal which is sent to the brain, enabling the mammal to make instant decisions about its environment to help it move around or catch prey," explained Professor Tony Prescott from the University of Sheffield. "The whiskers have another advantage over some other forms of tactile touch. Whiskers themselves are easily replaceable since the sensory cells are at the base of the whisker — not the top — unlike our fingers for example, which are more easily damaged and hard to replace."

Robots like Shrewbot will be ideal for exploring and mapping spaces where laser, acoustic, or visual sensors don't work very well, such as dark spaces, spaces filled with dust or smoke, or even in turbid water.

## FULL ASSEMBLY REQUIRED

Meet IkeaBot ... the first autonomous robotic system to assemble a piece of IKEA furniture. IkeaBot is an automated assembly system that directs the actions of a team of heterogeneous robots in the completion of an assembly task. The robots perform geometric and symbolic planning, assume different roles, and coordinate actions to complete the assembly. The project is developed by MIT Computer Science and Artificial Intelligence Laboratory researchers.

# COMBAT ZONE

## Featured This Month: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# BUILD REPORT:

## The Quest for a Different Kind of Flipper: Making the Machine

● by Zac O'Donnell

In last month's issue of *SERVO*, I wrote about my six pound flywheel-powered flipping robot named Threecoil. I focused on the new design for the trigger mechanism, and the iterations of testing and redesign that it went through before competing for the first time.

**FIGURE 1. Metal stock.**

This month, I will discuss the fabrication of some of the parts that made up the flipper assembly in Threecoil.

In **Figure 1**, you can see the pile of metal that started it all. The large aluminum tube was used for the coil drum, and the solid aluminum round was used for the flywheel and coil drum end caps. One of the small steel rings was used for the flywheel, and the channel and flat bar stock were used for the arm.

**FIGURE 2. Finished rings.**

**Figure 2** shows the flywheel and coil drum rings after I turned them down so they were uniform. I also bored out the .25" wall aluminum tube to .125" to remove weight.

The flywheel ring was then used for a test fit with one of the flywheel end caps while it was still on the lathe. The other one was held in place to verify that both sides matched properly (**Figure 3**).

Once the flywheel end caps were turned on the lathe, I also cut the end caps for the coil drum out of the same piece of round stock. **Figure 4** shows the two end caps with set screws tapped down through their centers.

These set screws stopped the coil drum from sliding horizontally along the coil drum shaft, and were counterbored into the coil drum ring to lock the rotating ring to the coil drum axle.

The final coil drum assembly used two small screws going horizontally through these two plates to lock those set screws in place (**Figure 5**).

After turning the flywheel end caps down on the lathe, most of the material in them was removed to save weight. In **Figure 6**, you can see that they were installed around the flywheel ring with cross-bolts — much like the coil drum end caps.

Once the flywheel was completed, I moved on to the first version of the rear coil plates.

One of these is shown in **Figure 7** with the corresponding rear bar installed in a groove.

This assembly — along with a matching one on the other side of the flywheel — was responsible for converting the tension in the rope into flipping force in the arm.

**Figure 8** shows the slide assembly that held the clutch roller. This part was jammed between the coil drum and flywheel to fire the arm.

The last part I made before the first test was the pair of weapon rails that were made out of .125"

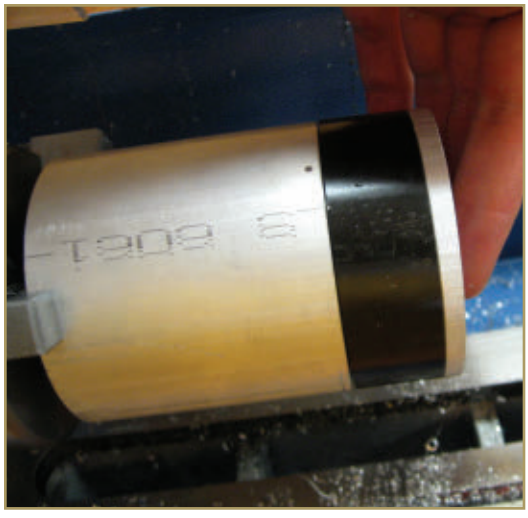


**FIGURE 3. Flywheel end cap test fit on lathe.**

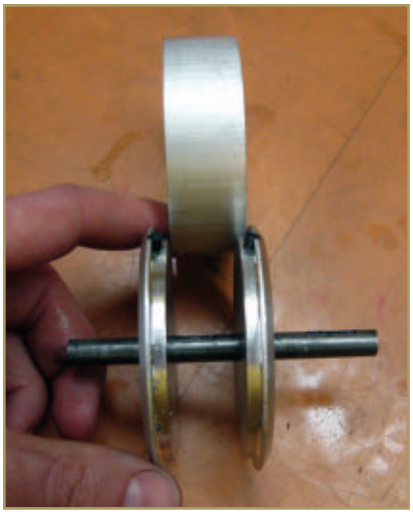


**FIGURE 4. Coil drum end caps.**

**FIGURE 5. Coil drum completed.**

**FIGURE 6. Flywheel completed.**

**FIGURE 7. Rear coil plate with rear bar.**

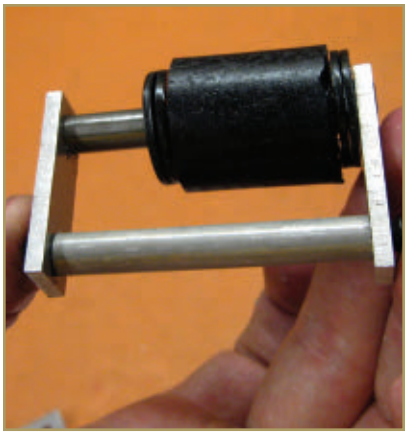


**FIGURE 8. Clutch slide carriage.**

thick aluminum angle stock (**Figure 9**).

After a few hours of assembly and adjustment, all of the parts were installed together in a single unit as shown in **Figure 10**.

The initial tests showed that the .040" Kevlar thread was not strong enough to withstand the force created by the flywheel, so I had to redesign and improve the rear coil plates.

The updated coil plates — one of which is shown in **Figure 11** — have space for up to a .125" thick rope which proved to be more than sufficient.

Once the system was working reliably, I formed the arm out of a piece of aluminum channel (**Figure 12**), then drilled some weight reduction holes and finished the front with a small titanium scoop (**Figure 13**).

**FIGURE 9. Weapon rail.**

**FIGURE 10. Entire assembly.**

**FIGURE 11. Updated rear bar.**

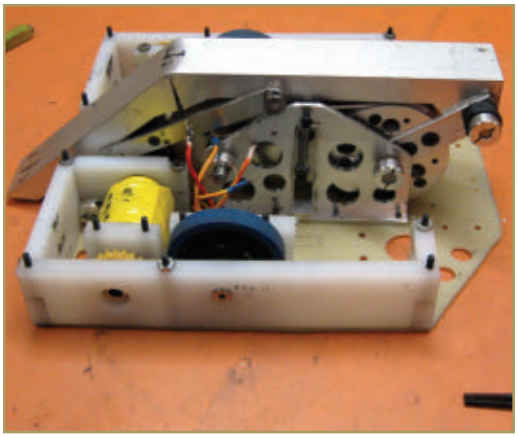


**FIGURE 12. Finished arm.**

This project pushed my precision fabrication skills well beyond any project before it, but I am satisfied with the results.

All of the components worked smoothly together after some fine-tuning and adjustments. In the end, the success of the project convinced me to try to scale it up to a 30 pound Sportsman class robot, but you'll have to wait for another issue to see how my quest continued. **SV**

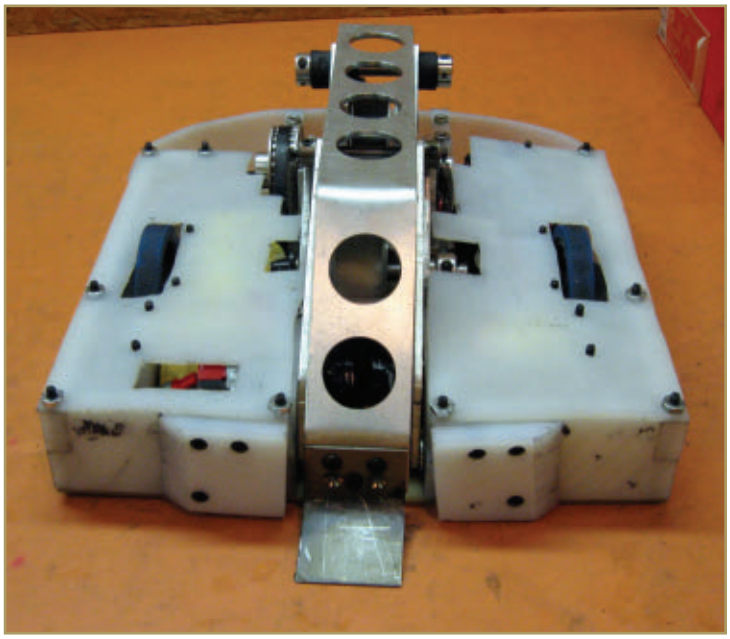


**FIGURE 13. Finished bot.**

# Then and Now — A Decade Later With Jim Smentowski

● by Kevin M. Berry

*We continue our series of articles with famous faces from a decade ago. The year 2003 inaugurated a new era in combat robotics, where our sport left the spotlight and tried to fly on its own. Grassroots events sprung up everywhere, as documented in our 2012 series of articles, "The History of Robot Combat." For 2013, we're taking a more personal approach, interviewing media stars from that time.*

*Jim Smentowski is the builder of one of the legendary bots in our sport: Nightmare. He held a dream job at George Lucas' Industrial Light & Magic when he got started in the sport. Leveraging his fame, he developed the "go to" web store for builders: The Robot MarketPlace (**www.robotmarketplace.com**). He graciously consented to answer some questions for our readers. He now sponsors an Insect bot fight series called Gulf Coast Robot Sports in central Florida.*

**Jim Smentowski and Nightmare.**

**Combat Zone:** It's been a decade since the "glory days" of televised robot combat. BattleBots™ encouraged me and dozens of others to join the sport. You worked your way up from competitor to television regular. Could you give *SERVO* readers a short version of how you moved from the pits to the camera?

**Jim Smentowski:** First, your robot had to compete its way through the brackets to even qualify for the televised matches — people don't realize just how many fights didn't make it to TV. Because I was involved early on, I was seeded in the rankings which helped, but I had to literally fight my way to TV. I was fortunate enough to have been pretty successful. Backlash (my 60 lb robot) ended up being ranked #2 after five seasons of BattleBots; Nightmare was the #7 ranked Heavyweight. My robots were very visual and it played well to the audience, and each robot builder had their own fans. One of my young fans built me a Nightmare out of LEGOs and mailed it to me. I still have it in my office. That kid's probably in college now.

**CZ:** You even were teamed with the late Gary Coleman in a promotional arrangement with UGO networks. How did that come about?

**JS:** UGO was my sponsor. They said they wanted to put a spokesperson on my team as an honorary member so I agreed. Then, they said "by the way, it's Gary Coleman." It was all very surreal. We treated him like a regular part of the team — no special treatment — and he seemed to really appreciate just being one of the guys that weekend. I even had him turning a wrench during some of those crazy between-fight repairs.

He was a pretty great guy, one of the few 'famous' people involved in the sport over the years that was genuinely enjoying themselves at the event and actually exhibited

true interest in the robots.

**CZ:** I got started in the sport because of the television coverage of BattleBots and Robot Wars. You started near the beginning, before the TV days. How did you hear about robot fighting, and how did you get started?

**JS:** I had moved from Colorado to work my dream job at Industrial Light & Magic and had been in California only about a month. One of my coworker's grabbed a VHS tape and said "Have you heard of Robot Wars? You gotta watch this ..." I watched a home video someone took of the 1995 Robot Wars competition. I was instantly hooked. I came home and talked about it endlessly to my wife. Like every day. In 1996, we went to the live competition as spectators, and then I knew I had to build a robot. I competed for the first time in 1997 with a backyard-built heavyweight robot named Hercules. My first match EVER was against Jamie Hyneman (before he went on to form Mythbusters) with his scary machine, Blendo, and he tore me apart. I knew I had to come back and try to beat Blendo. I spent the next two years designing and building Nightmare, specifically to defeat Jamie's bot. Sadly, I never did meet up with Blendo again.

**CZ:** Was it a huge disappointment to you when the show was cancelled and the sport slipped back into smaller and smaller events?

**JS:** Yeah, we knew that TV shows don't last forever, but we were hoping to get a longer run out of it. On the other hand, the bots were getting so much more powerful with each season, I think that for everyone's safety it's probably good that the momentum of the sport slowed down. The arena could hardly contain the Superheavies in Season 5.

It was also growing with unprecedented speed — there were something like 500 robots showing up for one season. One simply can't imagine the logistics of running an event with that many robots. The popularity of the TV show had taken it to a level we never anticipated.

Of course, we had also just rolled out our small side business called The Robot Marketplace to sell robot parts online at the exact time the show was cancelled. We were a little nervous, not knowing if we could support ourselves off of robotic combat once it went off the air. Plus, we had a baby on the way. Somehow we're still here, 10 years later, selling robot and hobby parts.

**CZ:** Tell us your favorite story about the fabled sportsmanship that competitors show in this sport.

**JS:** I saw it early on, at that Robot Wars event back in 1996 when I just wanted to gather information. I remember leaning over the railing of the pits, talking to many of the builders, asking whatever questions I could, since I had never done anything like it before, and they were all very friendly and eager to share information. Then the following year, after I got clobbered by Jamie's Blendo, one of the casualties was my (very expensive) Vantec speed controller, which I only had one of. Trey Roski (who later went on to create BattleBots) handed me one of his, shrugging his shoulders, "Hey if it helps you keep fighting, here you go."

The same sportsmanship continues still today. I see teams going out of their way to help other builders get their bots fixed between matches, loaning parts and contributing time, even if it means they will be facing them in the next fight. It is a great feeling to see this level of camaraderie.

**CZ:** Coolest win? Coolest loss?

**JS:** Coolest win is a hard pick. Defeating some of the top-ranked or famed robots always gets your blood pumping. I'd say beating Last Rites with Breaker Box in RoboGames 2011, beating Ziggo with Backlash in BotBash 2001, and, of course, winning the BattleBots Lightweight championship in 2000 are all highlights. I have to say I've also had plenty of great moments winning with my smaller (3 lb and under) robots too — the fun and adrenaline are not just reserved for the bigger bots!

Coolest loss was probably a tie between Sewer Snake at RoboGames 2011 (the two robots are both so animated, it's always a blast to fight him) and, of course, Nightmare vs. Warhead in BattleBots Season 5. Everyone was in anticipation of that fight. I was in such awe of their machine, it was an honor to fight them. I had fun even when losing. I just wish I could have torn up their pretty robot a bit more than I did!

**CZ:** So, it's been 10 years. You've turned your hobby into a full time career running The Robot MarketPlace web store, and now two brick and mortar R/C hobby shops. What's next?

**JS:** I think I'll start a TV show called "MythBusters." Kidding. I've had such a bizarre career path all the way from pizza delivery to movie effects, being on TV and owning a robot parts store, I couldn't begin to guess what might happen next.

My wife and I are celebrating 20 years of marriage this year, and I have two boys to keep up with. I'm always excited to see what life will bring next.

It's funny. I've worked with 220 lb robots all the way down to my six year old's 5 oz pinewood derby car. Both have to stay under the weight limits, but it's a heck of a lot easier drilling holes in balsa wood than 3/8" thick titanium! SV

# EVENT REPORT:

## RoboGames 2013

● by Ray Billings

RoboGames — the largest robotic event in the world (according to Guinness World Records!) — returned to the San Mateo, CA Exposition Center April 19th through 21st. This annual event has become the preeminent event for robotics, and this year was no exception. The crowds were large and energized, and the action was non-stop!

RoboGames has been running annually in the San Francisco Bay area since 2004 (the first year it was known as the Robolympics). The inspiration behind RoboGames was to have roboticists from different ideologies and bring them together to compete at the same event. This would hopefully allow some cross-pollination, and by bringing experts from so many differing classes together, everyone could gain some new skills in the process. This has created a very exciting atmosphere which keeps both competitors and fans alike coming back every year.

Robotics competitions in general are an international sport, and this year's RoboGames had teams of contestants from around the world — 703 robots from 17 different countries competed in 59 separate events.

Although RoboGames has competitions in multiple non-combat classes, it is always the combat robots that garner the most attention. The larger weight classes compete in a 40 foot square arena, with action in 60, 120, and 220 pound classes. Notably, there were several brand new machines in the mix which put on a great show for all.

Half the robots competing in the combat classes were rookie machines, including some medal winners — and what interesting medals they are! The medallions at RoboGames have always been works of art. In past years, medals have been representations of gears, scrolling LED displays with the winner's name and robot name, see-through planetary gearsets, and even artistic classic "Olympic" styled laurels. This year's medals were lighted busts of famous robots of the past.

First place gold medals were C3PO from the Star Wars franchise; second place silver medals were Cylons from the original Battlestar Gallactica series; and third place bronze medals were the more obscure Tik Tok, from the Land of Oz books.

The medals were cast in metal, and then plated gold, silver, and bronze, respectively. For a more in-depth look at their fabrication, you can find details at **www.evilmadscientist.com/2013/robogames-2013**.

**Gary Gin, winning his fifth gold medal in the Heavyweight class.**

In 60 pound lightweight action, there were 31 entries. The tough Brazilian bot, Federal M.T., put on a great show of power, dominating the class for the gold. Long time veteran bot, The Big B — a very tough and well driven wedge — took the silver. The sturdy

### TABLE 1 - ROBOGAMES 2013 WINNERS.

| | Gold | Silver | Bronze |
|---|---|---|---|
| **Combat:** | | | |
| 220 lbs | USA - Original Sin | USA - Sewer Snake | USA - Last Rites |
| 120 lbs | Brazil - Touro | Brazil - General | USA - Mortician |
| 60 lbs | Brazil - Federal M.T. | USA - The Big B | USA - Black |
| 3 lbs | USA - Raptor 2.2 | Brazil - Mini Maloney | USA - Attitude |
| 3 lbs - Auton | UK - The Box | Mexico - Upiitote | Mexico - Rompemadres |
| 1 lb | USA - The Bomb | USA - Captain Crunch | Canada - Kitbot |
| 1 lb - Auton | UK - Wanderer | Mexico - Pinito | Mexico - Telavas Telacara |
| 5.3 oz | USA - Tiny Terror | USA - Snuggle Bunny | USA - Atom Bomb |

pusher/rammer, Black (driven by eight year old Hannah Rucker), took the bronze.

In the 120 pound middleweight class, the field was larger this year than in any previous RoboGames with 35 entries. This was an even mix of tough veterans and many well-built rookie machines.

The always tough drum bot, Touro, from Brazil outlasted everyone to secure the gold. Another tough Brazilian bot, General, took the silver medal. The Mortician – with is horizontal spinning bar – took the bronze medal.

The 220 pound heavyweight class also had a large field, with 19 entries competing. The incredibly stout and well driven wedge bot, Original Sin, went undefeated as it has at many RoboGames events, marching its way to its fifth gold medal.

Crowd favorite, Sewer Snake, finished with the silver medal. The always menacing (to robots and arenas alike!) spinning bar of Last Rites took the bronze medal.

**Table 1** shows the results from the combat classes. A complete list of all the winners in all classes is available at **http://robogames.net/2013.php**). Congratulations to all the winners! SV

*Photo credits: James Darr Photography and Lem Fugitt (Robots-Dreams.com), and Windell H. Oskay.*

**The medals at RoboGames have always been works of art, and this year's were some of the best yet!**

**In one of the more debris-filled matches of the event, Heavyweight Last Rites dismantles Vlad The Impaler II.**

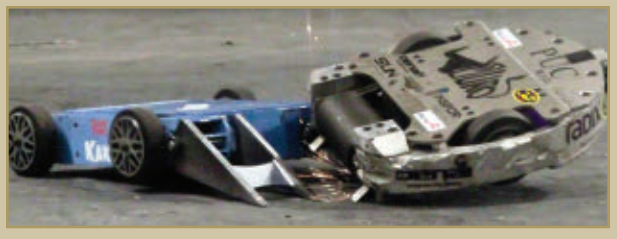
**Combat robotics is definitely an "all age" sport. Here, eight year old Hannah Rucker drives her Lightweight bot, Black on her way to a bronze medal.**

**Son of Ziggy launches his opponent over the rail. The flying pink robot here is called Super Fluffy Pink Bunny from the Land of Candy and Rainbows. Who says combat builders don't have a sense of humor.**

Sewer Snake and Predaraptor wrestle for Heavyweight class dominance. Sewer Snake wins this match on its way towards a silver medal.

Federal M.T. stands Texas Heat up on its end, en route to a gold medal in the 60 pound Lightweight class.

Veteran bar spinner, Mortician squares off against rookie Middleweight Taz. Mortician goes on to win a bronze medal in the class.



Touro grinds away on the front of rookie hopeful Kaku. Touro goes on to win the Middleweight division, while Kaku ends up taking fourth place overall.

The crowd loves flame throwers! Here The Great Pumpkin does a little BBQ on Touro Maximus.

Something completely new for this year's RoboGames — a flying combat robot! This particular machine was run as part of a multi-bot in the Heavyweight class and had a flame thrower weapon!

Last Rites giving a good hit to Son of Ziggy, with white titanium sparks flying everywhere to the delight of the crowd.

Exciting fights can lead to frantic repairs. Here, Son of Ziggy gets some maintenance between matches.

Future engineers, learning about robotics.

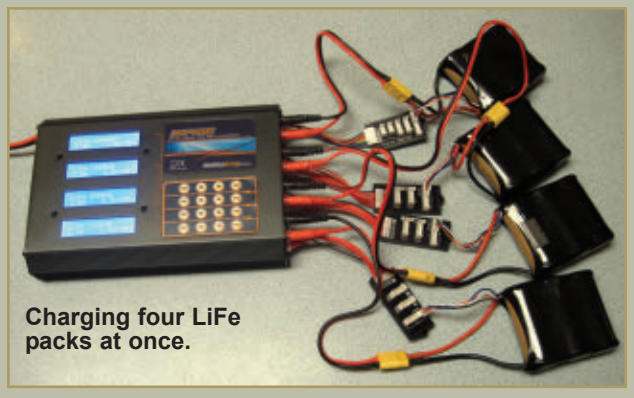
Even some of the spectators are robotic! R2D2 is always a crowd favorite.

The stands around the combat arena were packed all three days!

In the Heavyweight finals, last year's winner Original Sin takes on the 2011 winner Sewer Snake. Original Sin defends its title with another gold medal!

# PRODUCT REVIEW: HobbyKing HK4B6 Charger

● by Pete Smith



**Charging four LiFe packs at once.**

My growing fleet of mini Bot Hockey bots all use the same type of 2,600 mAH 3S (11.1V) LiFe battery packs, so I was looking for a charger that could "top off" as many batteries as possible at one time, while still being useful to charge my other 6S packs I incorporate on my bigger bots. The HobbyKing HK4B6 (approx $100 including shipping) seemed to meet the requirements. It can charge four batteries simultaneously, and can cope with all the usual battery types including the 6S lithium polymer and LiFe packs. It requires an 11-18V DC supply at about 20A to power it, but HobbyKing sells suitable power supplies if you haven't got one (about $75 shipped). The charger has a robust metal case with two built-in fans, plus four back-lit displays and four sets of buttons (one for each battery). It comes with four XT60 charging leads and a wide variety of adapters to let you power most batteries you may come across. However, it only comes with one of each type, so if you want to charge more than one of the same type of battery at the same time, you will need to get extra adapters. (I simply changed the plugs on my batteries to XT60s to avoid having to use any adapter.) Similarly, the charger comes with a variety of balance boards to suit the various types of balance plugs that battery manufacturers use. (Again, there is only one of each.) My batteries have Thunderpower type balance plugs, so I had to buy three additional balance boards on eBay so I could plug all four in. This cost about $20 for the three.

Once you get everything plugged in, it's just a matter of setting each section of the charger up to suit the battery attached. The user interface is not particularly intuitive (there is a manual), but it didn't take too long to get all four set up to charge 3S LiFe at 2.5A (about the right rate for my batteries).

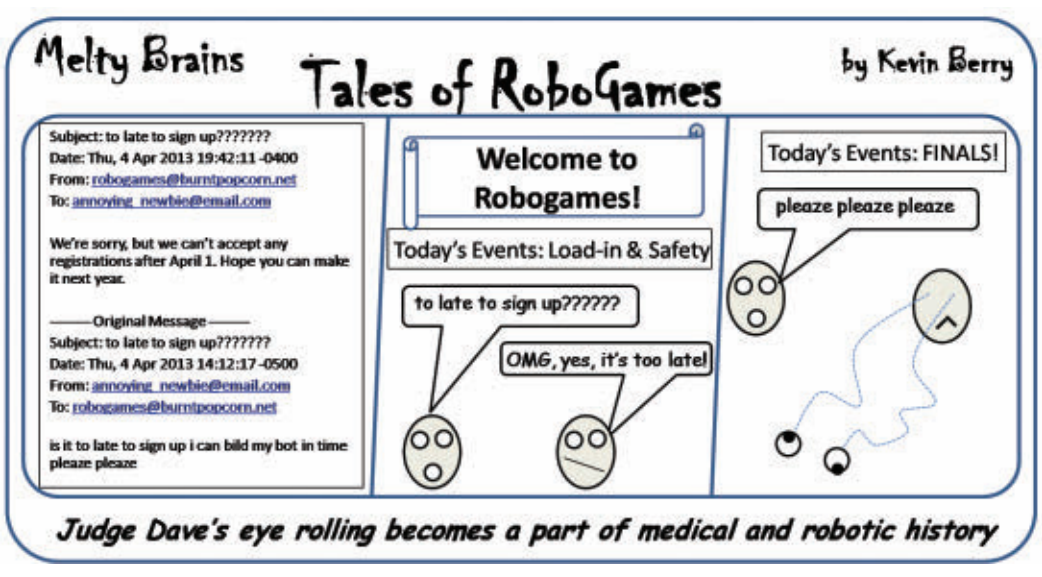
The unit can charge each battery at up to 4.5A for a 3S battery, but this drops to only 2.5A for a 6S pack.

In use, I found that having all the leads come out of the charger at the same end made it easy to confuse which battery was attached to which part of the charger. You need to be careful not to unplug the wrong pack or press the wrong set of buttons.

The charger seems a little more sensitive to input voltage than my existing iCharger 106Bs because it would shut down before they did if it was plugged into the same supply and set to charge at a high rate. The HK4B6 appears to work well and didn't give me any problems (other than what I just mentioned) through a whole day of Bot Hockey at a recent event.

It is convenient to have all four batteries on one charger, and it takes up less space in the pits. It's also a little cheaper than having four separate chargers, but it could also mean that if it fails you may lose all four at once.

I've found modern chargers to be pretty reliable and have decided to buy a second one so I can charge eight batteries at once and still be able to charge four if one fails. SV



# RESOURCE REVIEW:

## MFG.com

● by Mike Jeffries

**MFG.com** has been around for a while, but I only recently got around to trying out their services. They have a few rivals in the market, but the ease of use and large number of member shops make it the leader in the market.

What **MFG.com** does is provide a location for users to post quote requests for custom fabrication. Once you've posted a quote request, shops from your specified search region (US, North America, Global, or specific national and international locations) will then be able to see your quote request and bid on it.

In this stage of the process, you can specify when the quote is needed by, what parts, how many you need, who handles shipping, and when you need the actual parts. After that, you wait to see what quotes have come in and make a decision by the award date. Once that is completed and a specific shop has been awarded the job, it's down to you and them to handle payment and fabrication.

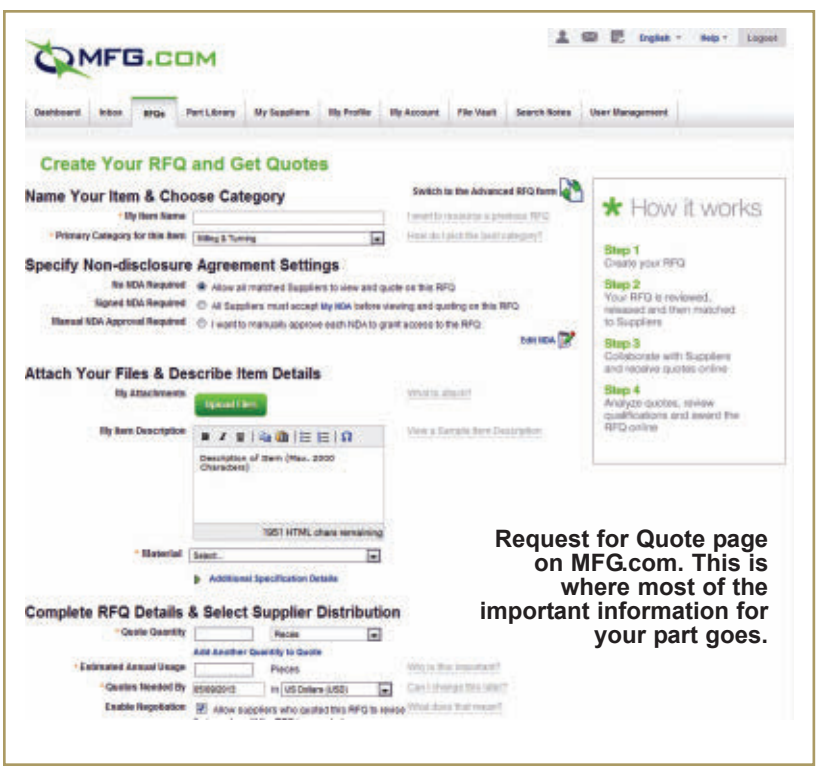
As a trial run of the site, I decided to have the somewhat complex weapon hub for the rebuild of my 1 lb robot Algos quoted. The design of the hub was somewhat setup-intensive and the requested quantity was only two units — which meant there were several possible issues that could arise, including many shops passing up such a small quantity and high initial setup costs relative to the machining time cost.

Within several days of posting the quote request, I had two submitted quotes: one for $300 (Shop A) and another for $100 (Shop B). Shop B also specified that at six units, the price would drop to $30 per unit with $10 shipping and handling. I also received a message from a third shop asking what other quotes I had received (Shop C). I informed Shop C that the best quote I had was from Shop B at $100. After a few days, they replied saying they would match their rate.

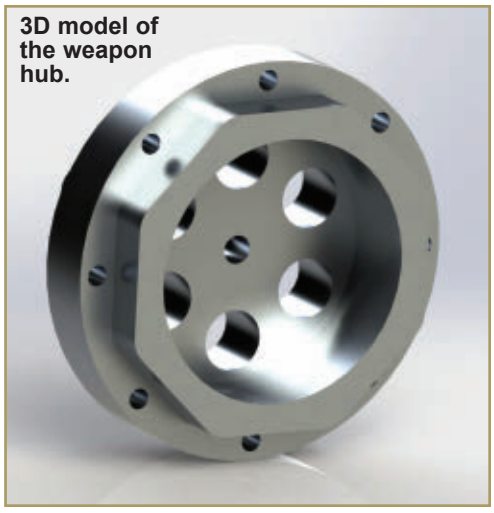
At this point, I decided that I would make my pick for fabricating the weapon hubs. Each of the shops had a profile page where they were able to post examples of their work, and where users could provide reviews of the shops.

Shop A was out, as while their reviews were generally quite positive, the $300 price point was much too far off of the other quotes to consider their services. Shop B had no reviews at this point but the sample parts appeared to be high quality. From looking into them a bit more, I could tell it was a very small operation. Shop C had mixed reviews, including one that was highly negative about the part quality and claimed that they outsourced manufacturing.

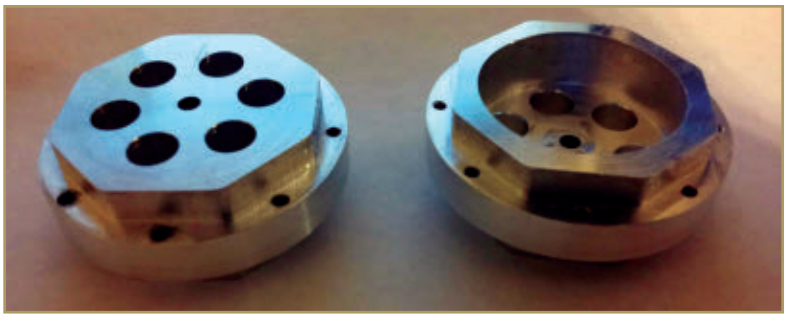
In the end, I decided to go with Shop B and awarded them the job. At this point in the process, you'll be dealing directly with the shop. In the case of Shop B, they did not require payment until I had inspected and approved the parts. This is something that is up to the individual shops, and will need to be discussed with them *preferably* during the quote period if you want to ensure a specific payment arrangement.




**Request for Quote page on MFG.com. This is where most of the important information for your part goes.**



3D model of the weapon hub.



The machined weapon hub from Shop B.

Two weeks after awarding the job, I had the weapon hubs sitting on my doorstep. I spent some time checking over the parts and all were within a reasonable (+- 0.005") tolerance. I have since assembled both weapon hubs and completed the rebuild of Algos.

Overall, getting the parts made through **MFG.com** was a simple process and was generally pain free. However, there are a few things you absolutely must do if you decide to use the service:

- Make sure your CAD models and part drawings are unambiguous.
- Make sure to be detailed in your comments on the parts.
- Start the process early.

Before giving my final thoughts on **MFG.com**, there are a few things on CAD files and part drawings that need to be mentioned.

**MFG.com** is set up to accept a wide range of 3D and 2D file formats for their quote requests. However, as part of that, they will often convert the files from a native (.sldprt in the case of SolidWorks) format into a platform neutral format to guarantee that the largest number of shops can quote your part. It is often the case that when the parts are converted from one format to another, that some of the part references may be lost.

To avoid this becoming an issue, make sure to provide a part drawing along with the file calling out special features like tapped holes that may appear as simple through holes due to the way the files are rendered. I personally suggest uploading the 3D model along with a .dxf or .pdf drawing of the part that has been fully dimensioned to minimize the risk of miscommunication during the manufacturing process.

After my experience using **MFG.com**, I would recommend the site as a means of finding a manufacturer for both low and high quantity parts. As long as you make sure the parts you are having quoted are clear enough that the shop doesn't have to "interpret" your design, it is a great way to find a shop that will be able to get you what you need.

As a final note, Shop B was RKB Manufacturing in Texas. They did a great job on the weapon hubs and were great to deal with. **SV**

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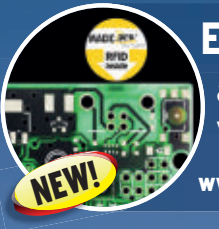

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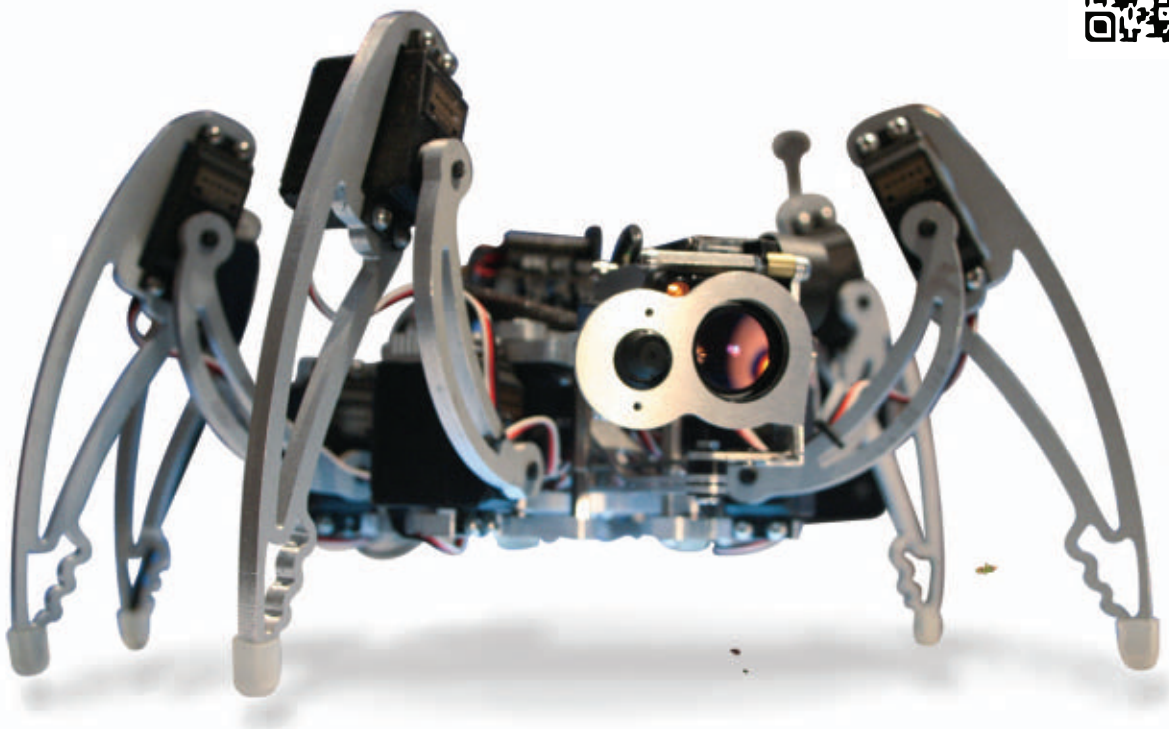

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# The Brain Behind Robot Combat League

By Dan Danknick

In the sci-fi movie "The Core," a group of scientists are faced with the dilemma of how to restart the spinning of the Earth's molten center. After outlining the impossibility of the task, they conclude with "...and we can't even get down there!" In dramatic fashion, one of them then asks "Yes, but ...what if we could?"

*Around the middle of 2011, Jeremy Whitham had the idea of making a TV series out of giant fighting robots. His plan was to entice father and son building teams to create eight foot tall robots in their garages, bring them together in an arena, and have celebrities control them — to the death!*

*In Los Angeles, Whitham was eventually introduced to legendary creature effects creator Mark Setrakian, who patiently explained that there is a large disconnect in the public's perception of robot technology and what is actually possible, and that what Whitham wanted was largely impossible.*

*Setrakian, however, had an idea to change the structure of the production. He alone would design and build the robots; Whitham could handle the casting. Each would do what they do best to pull off a TV show that is so fantastical, most viewers don't even believe it is real. It is, however, and here is how Setrakian went from idea to steel and hydraulics in his own "What if we could?" moment.*

*I am fortunate to trace my friendship with Mark back over 17 years, and was excited to speak with him about this amazing project of his.*

Prototype construction of the robot Hades commenced immediately, and only lasted four months. Mark was responsible for everything: the artistic design, the mechanics, hydraulics, electronics, and software, relying on his long and diverse background of creating animatronics and giant walking Army robots. Hades was presented and the show was immediately greenlighted — shooting would begin in another short four months!

To accomplish the construction of a dozen different 800 lb robots in a short time, he needed to put the project into an environment where it would succeed. That environment was Spectral Motion in Glendale, CA where he had previously worked on many movie projects. Spectral had the shop space but — more importantly — they had a team of finely skilled artists and fabricators that trusted Mark to direct them.

"I had so many things to personally attend to, I would say 'Here is a robot with an axe for a head. Here is my sketch of the head. Now, go design the remainder of the robot.'" In this way, Setrakian was able to hand off portions of the work while focusing on the highest risk areas.

In TV, time is money — especially when there are delays on set. So, the robots were designed to be reliable and to share common components. This also enabled proven design elements — like the hydraulic manifolds — to be standardized. "Putting a connector on a wire is an art form. I inspected each one under a loupe," Mark explained.

Although this was his first hydraulics project, the design of the robots is a marvel to behold. Each contains five independent sections of hydraulic power and control so

that if one is destroyed, the remaining parts of each robot can still operate. This allows the action to continue, but forces the contestants to develop new tactics on-the-fly as they lose resources.

There were no suspension cables — these robots really walked. Building a self-stabilizing bipedal robot is a huge task, however, so Mark came up with the idea of the "bloodline" — a hollow stabilizing arm (or boom) that comes out of the back. It is also used to protectively route the hydraulic power loop ("I wanted a high power/weight ratio and you can't get that with electric motors"), electrical power to run the valves and computers, and three fiber optic cables for control.

On the robot itself, the rod of each hydraulic cylinder provides force to move a joint, but also sends positional information back to the computer which, in turn, controls the valve through a 480 Hz algorithm optimized for this application. The PC/104 based computers receive their joint position commands over two of the fibers (transmit and receive) at 120 Hz, while the third provides a fail-safe mechanism that puts all valves immediately to neutral to "freeze" the robot. This is important because the hydraulic pump off-stage was producing 50 gpm at 2,000 psi — a dangerous amount of power.

Up on the control deck, two operators directed the robot through the "tech pod" and the "exosuit." The tech pod sports high-end USB flightstick controls to position the robot on the floor. A gait generator is always running in the software, and the flightstick controls operate on that gait to adjust speed and amplitude that is sent to the robot. Low amplitude and high speed make it shuffle its feet, while high amplitude and zero speed cause it to adopt a frozen pose. The exosuit has joints that model those of the robot under its control. Mark used rotary potentiometers on the joints to encode the position, but geared them up to achieve the highest data range over the limited motion angles. All of the joint data is transmitted over CANBUS, filtered, packetized, and sent down the fiber optic line.

During the battles, a broken hydraulic line would be allowed to squirt for a while and then be neutralized via a valve override command. None of the fights were scripted or altered in any way; "I would never allow that to happen!" While the robots were similar on the inside, "... each had its own differences and subtle advantages. I wanted this to be a contest between athletes," he revealed.

And a contest it was. Though they went through 20-30 broken cylinders in the course of the show, there was not a single failure of the mechanics or electronics which is absolutely amazing.

To be fair, Mark is an amazing guy. "Every project adds one new thing to my base of techniques. I am always in school," Setrakian commented. "What I do is at the intersection of art and technology. I speak two languages and my medium is robotics." **SV**

# MEAD GETS THE AXE

By Chris Olin

Ross Mead
Team AXE

This past February, the Syfy channel premiered a new robotic combat series unlike anything seen on TV before. The Robot Combat League (RCL) featured 12 six foot tall, 700+ lb, hydraulically powered humanoid robots fighting each other in hand to hand combat. The RCL has been likened to super-sized Rock'em Sock'em robots, and the hit movie, *Real Steel*. All of the robots were designed and built by robotic combat legend Mark Setrakian.

Each robot is piloted by two humans: a Tech that controls the robot's translational motion; and a Jockey that controls the arms and torso using a motion capture exoskeleton. The 24 contestants chosen for this tournament came from a wide variety of technical, athletic, and military backgrounds.

After the first round of combat, *SERVO Magazine* was able to sit down with Ross Mead — one of the pilots of the robot called AXE. Ross is a Computer Science PhD Research Fellow at the University of Southern California, specializing in autonomous robots that understand and use body language in social interactions with people. Ross has been involved in a variety of robotic competitions since 2000, and serves as a mentor to kids by teaching robotics to students in kindergarten all the way up to 12th grade — all around the world. His RCL partner was Andrew "The Squid" Montanez, a professional MMA (Mixed Martial Arts) fighter.

Andrew is proud to claim that the only jobs he's ever had have involved fighting and teaching martial arts. Andrew hosts the popular YouTube show, *MMA Surge*, where he instructs fight fans on bone-crushing moves. He is also a fight choreographer and stunt-man on Hollywood sets.

***SERVO*:** Ross, can you start by telling us a little bit about your background in robotics?

**Mead:** I've been working in robotics for over a decade. I participated in my first robotics competition in high school, and have been doing it ever since. I received my B.S. in Computer Science at Southern Illinois University Edwardsville (SIUE; **www.siue.edu**) under the advisement of Prof. Jerry B. Weinberg. There, I conducted research on multi-robot formation control (**http://roboti.cs.siue.edu/projects/formations/**); ontology-based communication protocols for multi-robot coordination; autonomous transportation systems and mixed-initiative interfaces with a self-driving golf cart; and integrating traditional and legged robotics into K-12 educational outreach activities (**http://roboti.cs.siue.edu**).

I am currently pursuing my PhD in Computer Science at the University of Southern California (USC; **http://robotics.usc.edu/interaction**). I work in the Interaction Lab where I develop models and algorithms for robots to autonomously understand and use body language in social interactions with people. This work is targeted at therapeutic interactions with populations with special needs, such as children with autism, people in post-stroke rehabilitation, the elderly, and people with Alzheimer's disease.

***SERVO*:** How did this help you during the filming of RCL?

**Mead:** My experience in robot competitions and outreach helped me a lot in RCL. I'm used to working as a team, troubleshooting problems, working under pressure, making split-second decisions when things change or go wrong, and — most importantly for a TV show — communicating technical information to the general public. Also, my work in body language really helped; I often have to annotate and analyze

human social behaviors and dynamics for my research, so I've become pretty sensitive to subtle movements.

During a fight, I would spend as much or more time watching our human opponents on the platform across from us as I did watching the robots; a simple drop of the shoulder of one arm of our opponent would give me a split-second warning that a particular punch was coming. This, compounded with the minor lag in the reaction time of the robot upper body (which was not present in the lower body), gave me an edge in the competition.

I'm also a big boxing and MMA fan, and have been boxing for two years myself. This provided perspective on how Andrew would approach a fight, and helped me work with him to adapt his fighting style from human combat to robot combat.

For example, Andrew had to fight his instinct to put his hands up to block his head, and instead put his hands down at his sides to protect the midsection and arms of the robot. Also, he utilized arcing hooks and uppercuts (as opposed to straight jabs) to prevent the actuators in the arms from extending to their physical limits (which would increase the risk of them breaking).

We were effective as a team in developing highly technical strategies that acknowledged and embraced the strengths and weaknesses of AXE and its opponents.

***SERVO*:** How did you become involved in the RCL?

**Mead:** There was a big casting call that went out to a bunch of robotics mailing lists in late 2011. I saw it and shrugged it off, thinking that there was no way that humanoid robots would actually be able to stand and trade punches for six minutes, or even six seconds. However, a friend of mine in the entertainment industry told me to reconsider and at least audition. I gave it a shot, and really played it off like a joke — I really didn't think the show would ever see the light of day. This actually removed any pressure on me during the audition. The casting director seemed to like how cool and calm I was about it, and they offered me the position. Before agreeing, I insisted on knowing about the technology, as I didn't want this to be a poor portrayal of myself or robotics. After understanding all the technical and production considerations, I was truly happy with the design decisions that were made — they really did a great job!

***SERVO*:** How would someone apply to participate in future RCL events?

**Mead:** As for participating in the next season of RCL, keep an eye out for the casting call — I'll be right in line with you, as I can't wait to get behind the controls of AXE again!

***SERVO*:** A common criticism of the RCL is that the contestants did not have any part in building their robots; they were merely assigned a robot that was already built. Can you give us some insights into why the show was done this way and the skill sets needed to design and build a machine like these robots?

**Mead:** This isn't the DARPA Grand Challenge and this isn't NASCAR. No one is lining up to sponsor the construction of an eight foot tall half ton fighting robot for a TV show. This will change in the future as robot sports become more popular — much like it has for professional gaming — but that time is not now. It took a lot of courage for Syfy to invest in something like this — it was risky. To ensure a worthwhile investment, they needed to be absolutely sure that all competing robots would consistently function in a standardized and safe way.

The best way to do this is to go with a single source with lots of experience in robotics and entertainment — in this case, Mark Setrakian and Spectral Motion. And they did an outstanding job!

Expertise in mechanical, electrical, and computer

engineering is required for the construction of these robots; creative and artistic abilities are also needed to design and manufacture each robot as a unique fighting character. The people with the skills necessary to take on a project of this magnitude likely already have jobs in which they're using those skills — but they're probably not being paid to build fighting robots.

Even with the right skillset, a non-millionaire hobby roboticist isn't going to construct one of these in his/her garage. It currently takes more time, money, resources, and personnel than any of us have. These robots are a huge scale up — in terms of both size and cost — from the days of Robot Wars and BattleBots, and it will be a while before it becomes more accessible. I can only hope that a show like Robot Combat League inspires people to pursue these skillsets academically and professionally for robot sports of the future.

***SERVO*:** What can you tell us about the robot's controls?

**Mead:** The controls for the Tech were easy to understand, but incredibly difficult to master. There are three main controls: (1) a throttle for the height of the robot (crouching, standing straight up, or somewhere in between); (2) a throttle for the speed of the step; and (3) a joystick for both the direction and stride length of the step. The height was important — crouching made the robot incredibly stable and helped protect the midsection but limited the length of the step; standing straight up allowed for long steps, but made the robot less stable and put the midsection at risk of a punch.

The speed was important — move too slow and an opponent could take advantage of your instability due to a foot being off the ground; move too fast and the feet would often slip or sort of "chop" at the ground. The direction and stride length were important — both short and long steps often resulted in slipping and chopping. On top of this, you're dragging a big, heavy T-bar behind the robot, which helped with stability but hindered mobility. It was all about finding a balance between the controls as you were moving, while also coordinating with the Jockey to land solid punches.

I found the best combination of controls was keeping the robot at about 75% of its maximum height and around 90% of its maximum speed. Most would simply move the joystick in the direction of desired motion and this worked fine. However, I discovered a trick with the joystick that no one else figured out in the competition — and I kept it a secret.

If you watch our fights, you'll notice that AXE sort of twists and wobbles from one side to the other when it moves. This is because, instead of simply pushing the joystick in one direction, I would actually rock it side-to-side around the intended direction of travel. I discovered that doing this would slightly lift the T-bar on one side which created a brief single point of contact between the T-bar and the floor, as opposed to two; this made the robot much less stable, but allowed AXE to pivot around the T-bar as opposed to dragging it.

It was very difficult to control, as I had to keep the "beat" of the step in my head (you can sometimes see me bobbing my head with each step!). However, as illustrated in our fights, it allowed us to rush our opponents and dominate the center of the arena. It was very effective!

I absolutely loved being behind the controls of the robot — I felt a bit like Iron Man, or a Voltron or Gundam pilot!

***SERVO*:** Your profile on **syfy.com** mentions you have competed in a slew of competitions across the county. Other then RCL, what type of robotic events do you enjoy?

**Mead:** I was first introduced to robotics in 2000 when a Prof. Weinberg invited a team of high school students (myself included) to compete against the university undergraduates in a robot Sumo match. My team went on to win that competition and many more — I was hooked! I began working with Prof. Weinberg in 2004 as an undergraduate student at SIUE, developing new robot competitions to foster interactions and collaborations between K-12 schools and higher education (**http://roboti.cs.siue.edu/competitions/**). My personal favorite was an autonomous urban search-and-rescue competition (which was part of a class) — it was entertaining, drew quite a large crowd, made the local news, and — most importantly — has real world applications!

Since 2003, I have expanded to national and international robotics competitions as a participant in the Botball Educational Robotics Program (**www.botball.org**). Like many robotics competitions, Botball reinforces principles of electronics and mechanical design; however, what really sets it apart is its focus on programming, robot

sensing, full autonomy, and student-driven (as opposed to mentor-driven) development. The sensing, processing, and motor technology gets better and better every year — check it out!

I worked on my favorite competition robot in 2007-2008, leading the software development of a custom autonomous golf cart called "Road Runner." Road Runner was designed to compete in the Mini Grand Challenge at Penn State Abington (**www.ecsel.psu.edu/users/avanzato/robots/contests/outdoor/**). It is currently being used by researchers at SIUE as a platform to investigate how to better design mixed-initiative interfaces for shared autonomy transportation systems. A full description of the system is at **http://robotics.usc.edu/~rossmead/docs/2008/2008MeadEtAl_AAAI08-WS08.pdf**.

***SERVO*:** Your profile also mentions you serve as a mentor to kids, teaching robotics to students in kindergarten all the way up to 12th grade. What types of programs are you involved in and what do they teach?

**Mead:** As a student at SIUE, I participated in a lot of outreach events targeted at engaging K-12 students in hands-on robotics activities to promote STEM (Science, Technology, Engineering, and Math). In 2006, I became a Botball instructor, teaching workshops all over the world; coordinating and hosting regional events; and assisting in the design of the game each year. Similarly, in 2008, I began mentoring a number of teams for the FIRST Robotics Competition and FIRST LEGO League (**www.usfirst.org**), as well as for VEX Robotics (**www.vexrobotics.com**).

I currently serve as a research fellow of USC's Body Engineering Los Angeles (BELA) program (part of the NSF GK-12 initiative). For BELA, I teach two days a week at a local middle school, integrating my research on sociable robotics into the STEM curriculum. This year, as part of an NSF ITEST grant, I organized the Greater Los Angeles Botball Regional at USC; it is currently the largest Botball regional in the world.

I have documented my experiences and insights using robotics in K-12 education in a book chapter, entitled, "From Grade School to Grad School: An Integrated STEM Pipeline Model through Robotics" (**http://www.igi-global.com/chapter/grade-school-grad-school/63421**).

***SERVO*:** Do you believe that shows like RCL can help inspire youth to get involved in science and technology?

**Mead:** "Awesome." In the most literal meaning of the word, awesome is the only way I can describe my experience on Robot Combat League — seeing the size, the power, and the look of the robots and the production as a whole, I was genuinely in awe. If I felt this way (even after years of working in robotics), I think the youth had to have felt it too — and it must be inspiring.

Robot competitions have been used for years to get students interested in STEM, and research suggests that they have lasting outcomes across a number of metrics. Robot Combat League kicks the competition up a notch, taking robotic characters from our TV screens and imaginations, and bringing them to life on an epic scale! Every time I walked onto the set, I was stepping into one of my childhood dreams — I was a superhero! If that isn't inspiring, I don't know what is!

***SERVO*:** Is there anything about the RCL you would like to see done differently?

**Mead:** This marks the first time that a robot competition of this type and scale was attempted, and from it comes insights that will influence technical and production decisions for future ventures. For example, we saw a lot of actuators and mounting brackets breaking, either by being struck by another robot or by pushing the robot beyond its own physical limits. Breaking an actuator or mounting bracket is better than breaking the underlying mechanical chassis of the robot; however, I can see some opportunities to better reinforce and protect these delicate mechanisms while keeping the chassis safe at the same time.

Also, as dynamic balancing technology develops and actuation systems become smaller and safer, we can expect to someday see these robots quickly moving in the arena without the heavy T-bar. This iterative design process is at the heart of engineering, and will only serve to grow robot combat and robot sports in general. In the meantime, I'll settle for being able to take my RCL robot home. **SV**

*Team AXE lost their second round fight to Team Brimstone.*

# Robot Combat League

## As seen through the eyes of a contestant

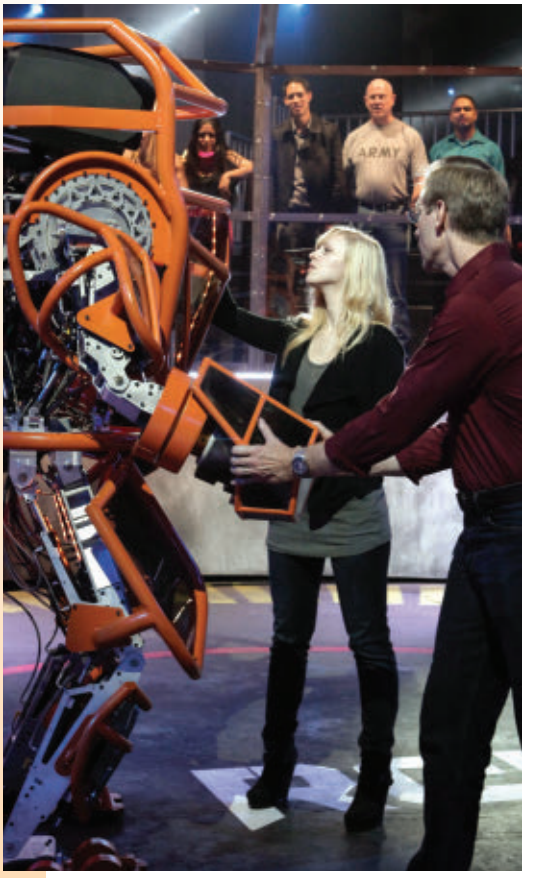
by Dave Shinsel

Discuss this topic at **http://forum.servomagazine.com.**

*I feel the adrenaline building as we do the final pre-fight checks on our massive robot before the match. We need to make sure all of the joint pins are secure, the actuator mounts are not fatigued or cracked, and the hydraulic and pneumatic lines are tied down so they won't get ripped out. We examine the armor on Crash's arms; we're worried about that. The armor has been bent back to shape since the last fight, but still limits Crash's mobility.*

*As my daughter, Amber, reaches up to check a shoulder joint, I am awed by the sheer size of Crash. He's certainly not the scariest robot in the competition, but it still feels wrong to hear Amber call 826 pounds of walking destruction "cute." As he stands at the entrance to the tunnel that leads into the arena, Crash's seven foot nine inch tall frame looks like it will just barely clear the tunnel roof. With our checks complete, we wipe off the last of the slippery hydraulic fluid from Crash's feet to maximize traction, even though we know it won't be long before he is drenched in more fluid from the upcoming mayhem.*

*"Ready for pressure?" The call comes down from the engineer at the safety override console. "Ready," we yell back as we step back from the robot. "Clear the bot! Going to half pressure," he calls out. "Robot clear," we respond. "Half pressure! Stand clear!" I watch Crash power up, his legs straightening the few inches needed to take the weight of his frame off of the maintenance stand. One of our pit crew dashes in behind the robot and removes the stand, then shouts up "Stand is clear!" I hear the hydraulics whine as the safety engineer calls out, "Going to full pressure!" I watch carefully for problems as the engineer moves Crash through his startup routine, testing the range of each joint and actuator. I need to make sure there are no leaks or cables getting pinched.*



**Dave and Amber Shinsel with Crash.**

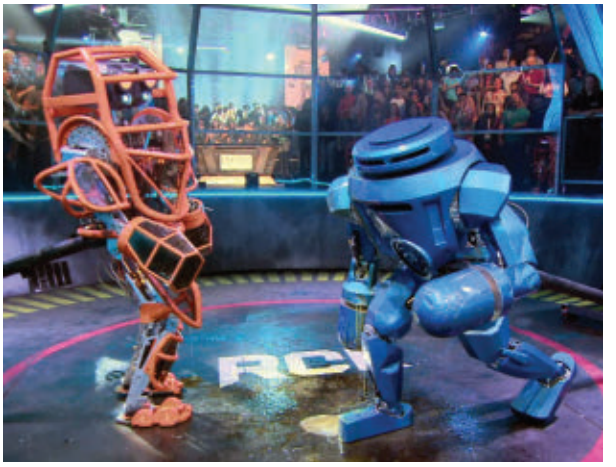
## Turn Your Weakness Into Strength

Satisfied that Crash is ready to go, Amber and I step over to our ready room to go over any final strategies.

This will be our second fight. Our first fight against Steel Cyclone was the first time anyone had ever walked two giant humanoid robots into a ring and started pounding on each other. We really had no idea what strategies would work, and we were still getting used to how to control our robot. We've watched six fights since then, and learned a lot by observing our opponents. Tonight, we go up against Brimstone.

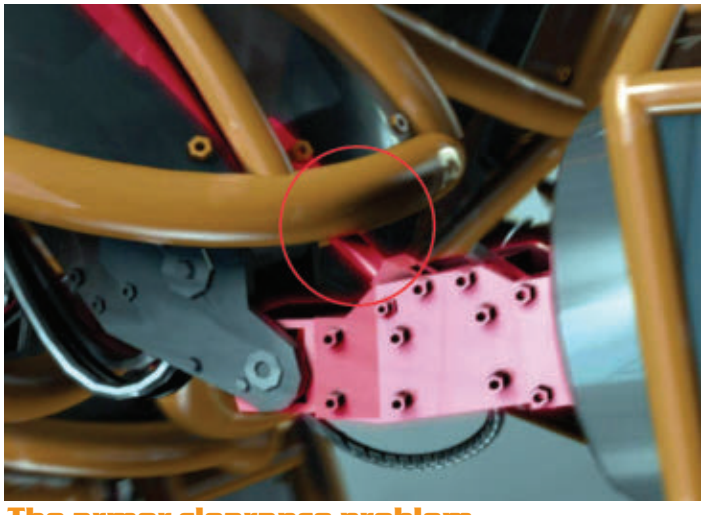
He is a big, hulking brute with padded leather armor that punches just bounce off. As the "Jockey," Amber controls Crash's arms. As the "Tech," I control the legs. It's critical that we work together in sync, but we're sure that the special bond between father and daughter will help us here. Plus, since we are both engineers, our brainstorm sessions have paid off with what we hope will be winning tactics.

First, we know our robot's key weakness is that his arm actuators break easily. To turn this to our advantage, Amber figured out how to twist back and forth in rhythm to get a broken arm swinging, and turn it into a deadly mace. Second, hydraulic fluid is slippery. Very slippery. When our arm actuator breaks, it inevitably sprays hydraulic fluid everywhere, so our strategy is to turn our broken arm towards our opponent and soak him with our own



**Crash defeats Steel Cyclone.**

Dave and Amber controlling Crash.



The armor clearance problem.

Crash catches Brimstone by surprise.

hydraulic fluid. Once Brimstone gets slippery, we can push him into a corner and land a flurry of punches while his mobilization is restricted. Plus, with all that leather that's on him, it's going to be hard to clean out the fluid between rounds. So, Brimstone should be dripping and slipping for the whole fight.

"Devonric is hyper-aggressive," says Amber, referring to Brimstone's Jockey. "He'll expect us to be cautious and come out slowly. He's expecting an easy win." "Yes," I agree. "Let's surprise him ... I want to come out really fast and try to catch Brimstone before his stabilizing bar is even out of his tunnel." "Yeah, I really like that." Amber then replies, "It will put him off balance." "And as a bonus," I continue, "regardless of which robot takes damage, any hydraulic fluid that spills will be on their side of the arena. We can make sure they stay in the fluid and get less traction." "That sounds great," replies Amber with a mischievous smile. "Just remember to push him into the wall like we discussed, so I can really hammer on him."

Just then, the call comes over the loudspeakers: "Fighters to your pods!" I feel my adrenaline spike with

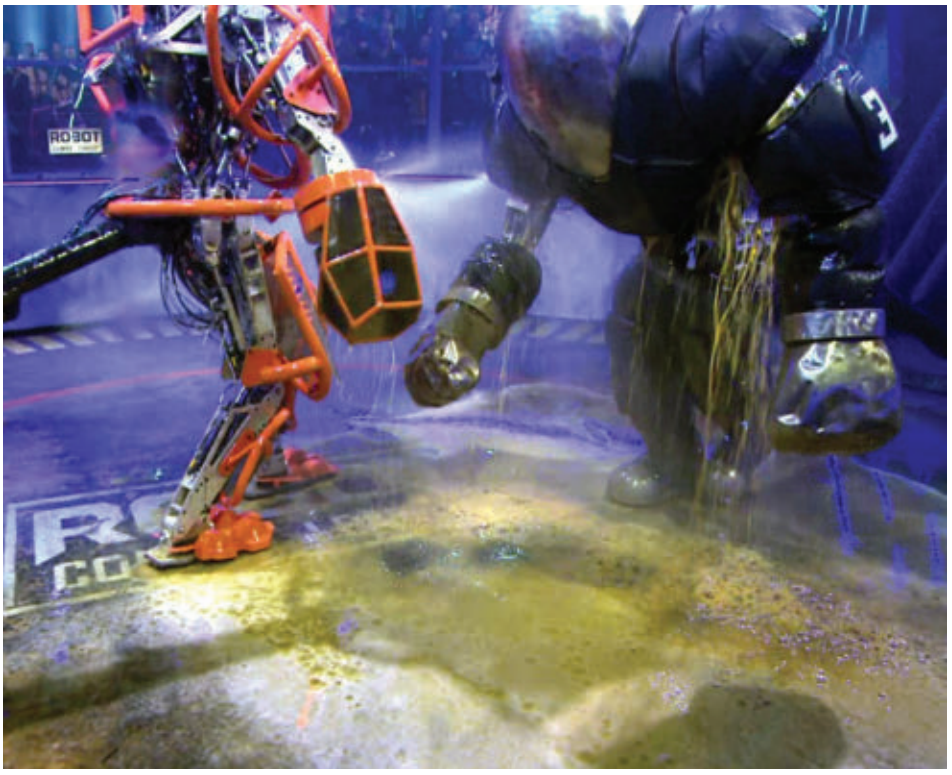
**"We never expected how loud the fights would be. Imagine being in a steel factory, with people beating on metal with 40 pound hammers! Now, picture that noise being drowned out by a screaming audience! It was so loud, we could barely hear the siren that signaled the end of the rounds! It was very hard to hear each other, so I got in the habit of watching Amber out of the corner of my eye, so I could see what she needed me to do."**

anticipation as we climb up the stairs to our fighting stations above the arena. The crowd is cheering as we emerge onto the fighting platform and our opponents Devonric and Russell step out onto theirs. Devonric is pretty cocky, dancing on the platform and taunting us. Yeah, he definitely thinks this will be an easy win. His partner, Russell is more reserved and disciplined. He's smart, and that worries me.

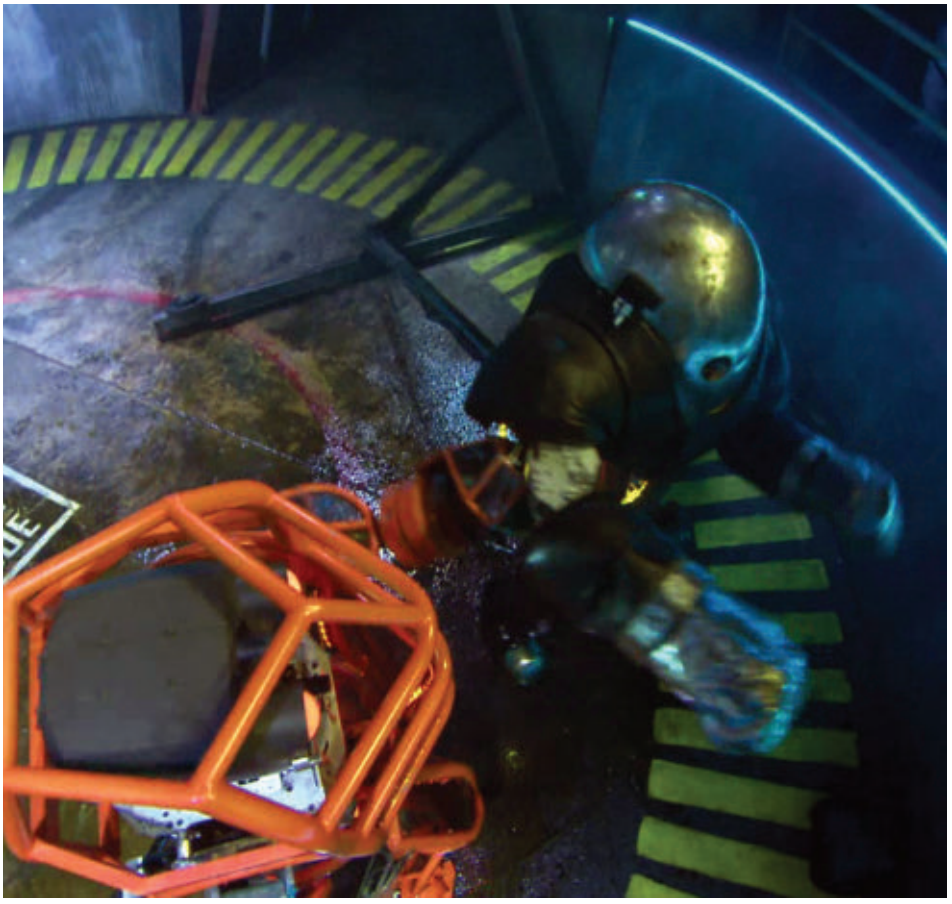
I help Amber strap into the exo-harness that translates her movements into the signals that will control Crash's upper body, and then help her move forward to the edge of the fighting platform. She tests the fit and movement of the harness, knowing that a good fit is critical to assure our robot will follow her motions. Looking at the control computer, I can see the harness accurately tracking her as she twists and leans side to side, and practices a few punches. I notice she's keeping her elbows up to avoid one of the situations that can cause our arm actuators to break.

As Amber settles into her harness, I climb into my pod, strap into my chair, and check the action of the joysticks and levers that control Crash's lower body. While the exo-harness the Jockeys wear makes upper body control fairly intuitive, the legs are a bit trickier. The joystick on the right controls the step direction; the levers on the left control the knee bend, step speed, and step length. Get the wrong combination and the robot will slip, hop, or jerk, and sometimes go into weird oscillations. I've seen contestants even break their own leg actuators by moving wrong.

All this would be difficult enough, but the robots also have a long boom rigidly attached to their backs that ends in a stabilizing T-bar. The pressurized hydraulic fluid, fiber optic cables, and power cables all run down the inside of the boom. Walking with it is kind of like towing a trailer. If you want to step to the left and back, you first must step to the right, then back up, then sidestep



**Round 1: Brimstone in a pool of hydraulic fluid.**



**Crash traps Brimstone in the corner of the fighting arena.**

**The Brimstone kill shot.**

left. Oh, and you need to make sure you don't back your T-bar into the side of the arena or into the tunnel where it can get stuck. Of course, you have to keep all of this in mind while trying to fight against another 700+ pound robot intent on destroying you. Fun!

The engineer at the safety override console calls over to us. "Ready for control?" I put my controls at neutral as Amber straightens and puts her arms down. "Ready," we call in unison. "Clear the bot! Robot going live," he calls out. "Robot clear" echoes back up from the tunnel. "Robot is live," he yells over to us.

I watch Crash on my tunnel cam as I do a few experimental knee bends to assure Crash is responding well, and settle in to wait for the call to enter the arena. I look over to Amber and say, "Here we go, are you ready?" "Yes," she replies. "Remember to stay to their left initially to throw Devonric off. He likes to use his right hook a lot." "Okay, let's kick some bot," I shout back over the noise as the lights change and the crowd starts yelling.

RCL Host Chris Jericho walks out to the edge of the arena. I can hardly hear him over the crowd as he yells "Crash, Prepare for Battle!" Watching my tunnel cam, I march Crash out the tunnel and up to the yellow starting line, making sure I don't step over it as that will incur a penalty. Now that Crash is out of the tunnel, Amber can check out how Crash is responding. She does several big twists followed by some jabs and a couple of round-house punches, and is satisfied we are ready.

## Round 1

The lights change again as Chris leads the crowd in the countdown. "Three ... Two ... One ... Fight!"

Our opponents expect us to be timid and slow. We definitely surprise them by rushing out as Amber immediately starts pounding on Brimstone on their side of the ring. Brimstone quickly springs a leak in his left arm, but it's not slowing him down. Amber is punching hard when our right arm breaks and starts gushing fluid. True to our plan, Amber keeps swinging the damaged arm, soaking Brimstone's feet and side. I shift right to lure Brimstone close toward the wall, and then suddenly sidestep left, then forward. Now next to him, Amber twists and starts punching Brimstone in the side. Brimstone steps further right, trying to avoid her hits and we follow, pinning Brimstone to the wall to limit his mobility.

As Amber delivers a series of kidney punches from the side, Brimstone catches on fire! Amber continues pounding away and breaks Brimstone's right arm actuator. The hydraulic fluid that's spraying puts the fire out as the referees blow the horn to tell us to separate. We back off and both robots return to the center of the ring. The horn blows again, and we engage. With just 10 seconds left in the round, Brimstone starts gushing fluid from his midsection from all the pounding, and starts to collapse just as the round ends.

This is definitely not what Team Brimstone expected from the "father/daughter" underdog team with the cute looking robot!

As we unstrap and hurry down to inspect Crash, our pit crew puts the maintenance stand under Crash's boom and the control engineer shuts down the hydraulic pressure so we can safely work on the robot. We have 20 minutes and two assigned pit crew techs to assist us with damage repair. We know we have a broken right arm actuator, and I ask the techs to start pulling that actuator while I inspect the left. We discover that the armor mounting bracket of the left arm has bent, causing the armor to interfere with the arm movement. This worries me, because if Amber bends that arm too far during the next round, our own armor will break our actuator. I discuss it with the control engineer, and we decide to limit the range of motion in the robot control software. I go back to helping replace the right arm actuator, and we get it done in less than 10 minutes. I remember the first time I replaced an actuator; it took me over 30 minutes. (By the end of the competition, I would be so practiced at it that I could replace one in about five minutes if I cut a few corners.)

With the actuator in, I start to replace the armor on the right arm, only to discover that its bracket is also bent and the armor will interfere too much with our right arm range of motion. Rather than limiting our right arm, we decide to leave the armor off. It's a risk, but we don't see a better option because there aren't any tools strong enough to bend the heavy bracket back into shape in time for the next round.

As I help Amber finish wiping the rest of the hydraulic fluid off of Crash's feet so he won't slip, we discuss the fight so far. We are feeling optimistic. We definitely won

the first round with Brimstone taking significant damage, but we know that can turn around in a heartbeat. We pressurize Crash and test the range of motion on our arms. While the left is somewhat limited, we can live with that. We finish up just before the horn blows ending the repair period. We are ready to go for the next round!

## Round 2

We come out even faster this time, dashing across the ring. Brimstone is slipping and slower to get off the line, and we catch him before he can get his boom out of the tunnel. This limits their movements, allowing Amber to really hammer on Brimstone. Amber nails Brimstone in the head making a huge dent. I think she enjoyed that after Devonric's pre-fight taunts.

The rest of Round 2 is pretty even, with each robot landing good solid punches. Russell is demonstrating great footwork, making it hard for me to press our initial advantage, and Devonric is doing a good job blocking and timing his punches. The final punch from Amber bends the actuator on Brimstone's left arm causing it to spray fluid, but we know that's not going to hurt them much. We're certain that they'll be able to fix the damage during the repair time without a hitch.

As we run down to the pit, I confirm that Crash only has minor damage on the left arm, so as one of the techs works on that, I go over the rest of the joints and fittings, making sure nothing has worked itself loose under the pounding. My only worry is Amber pulled her shoulder during that round; I'm concerned she might aggravate it in the next one. With repairs done, Amber and I go over the robot, cleaning up every bit of hydraulic fluid to make sure we are not dripping. This fight is close enough that any small thing could tip the balance.

Another concern is the rule for a third round knockout; if you are knocked out during the final round, you automatically lose the entire fight. Amber says, "We just have to be very careful in this next round, and not get knocked out." "Yes," I agree, "but this goes both ways. You have been pounding on their armor. I think their armor and the actuators below have been weakened significantly. We're pretty sure we are ahead on points, but we don't want to leave it to chance. If you see a good opening to take them out, go for it."

## Round 3

As we come off the starting line, our boom gets hung up in the tunnel, slowing us down momentarily. Team Brimstone has figured out our strategy, and takes advantage of our delay to come out fast, meeting us on our side of the arena for the first time. However, we quickly push them back into the center. Both robots are swinging away trying to get some solid hits in,

**"I am incredibly proud of Amber. She was so fierce, and so smart. I think she is a great role model for young women, proving that they can do anything they set their minds to."**

**Scorpio cuts AXE in half.**

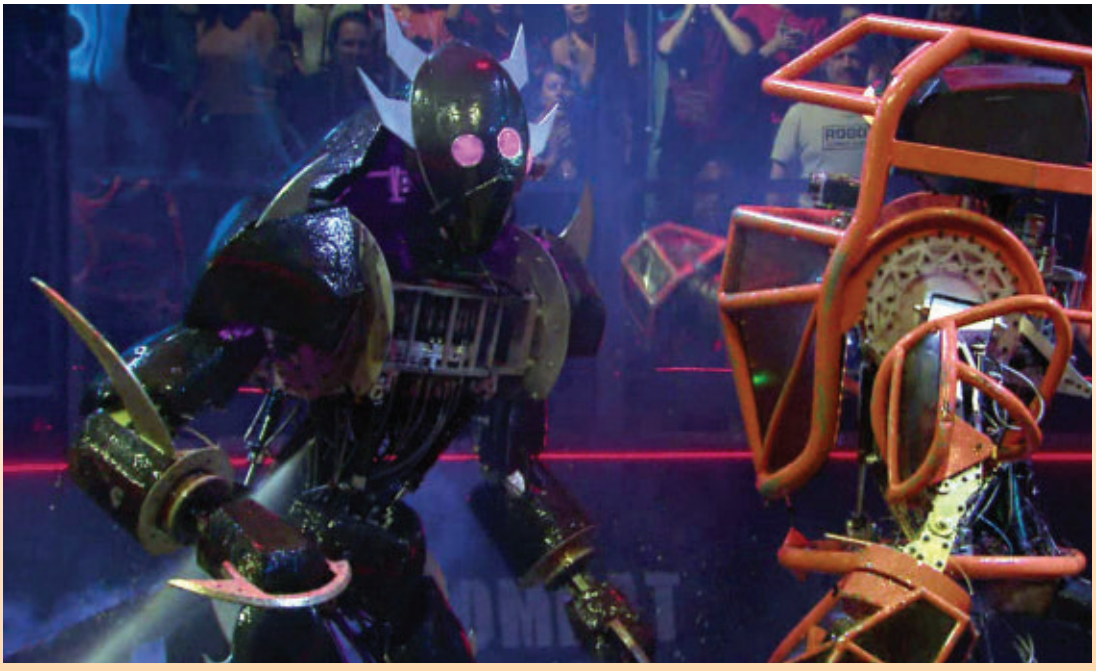
while at the same time blocking the opponent. The fight seems to be evenly matched, when Amber and I both see Brimstone momentarily pull both arms back, leaving his entire front exposed.

Out of the corner of my eye, I see Amber pull back for what I can tell will be a massive hit, so I step forward just as she swings. Her punch times perfectly with my step, and Crash's fist blasts right through the armor and steel actuators of Brimstone's torso, sheering the hardened steel like butter and traveling completely through to Brimstone's spine. As she pulls back for another punch, Brimstone topples forward, sparks and smoke flying from his destroyed mid-section. We back off as Brimstone collapses forward and catches on fire! The horn sounds, ending the match, but we can hardly hear it over the screaming of the crowd. We've done it! We've defeated the fearsome Team Brimstone!

We're almost in a daze. This puts us into the semi-finals! Then, we realize that this also means we will have to fight the most feared robot in the competition: Scorpio. With razor knives on his fists, Scorpio has already cut two other robots completely in half. Not only does Team Scorpio have a fierce robot, their Jockey, Diana knows how to use those knives to dig into a robot to rip out wires and hoses. Plus, Scorpio's Tech, Chris is very good at controlling the feet. But, that's for another day.

For tonight, we'll celebrate and enjoy the feeling of victory!

## Epilog



Scorpio without his chest plate.

Team Crash went on to fight Scorpio in one of the best fights in the competition. True to form, Crash quickly broke his arm, but Amber brought her "broken arm mace" strategy into play with deadly effect, completely knocking the chest armor off of Scorpio. At one point, Chris maneuvered Scorpio to the side and behind Crash, and Diana dug her knives into Crash's side. However, Dave and Amber managed to get off the hook and turn the tables, forcing Scorpio into the corner while Amber pounded on Scorpio.

In the third round, Scorpio got a long "mega drill" weapon, but again Team Crash managed to avoid being eviscerated by it, and used their less powerful weapon to hook Scorpio's chest plate and rip it off for the second time. Amber tried to land a killing blow into Scorpio's exposed chest, but Diana blocked skillfully, preventing a knock-out. The battle ended in a tense judge's decision, but once again Crash emerged victorious, winning two of the three rounds.

In the final Championship fight, Crash slugged it out with Steampunk in an epic five round battle that lasted over two hours. In the first round, Crash broke both arms, but that did not seem to slow down Dave and Amber at all. Amber twisted her body back and forth, and pounded Steampunk until he collapsed just as the bell sounded. Crash dominated Steampunk in Round 2, and was fighting strong in Round 3 when suddenly his left hand flew off. That round was awarded to Steampunk.

The damage to Crash's wrist was too severe to fix in time, and Crash had to go into Round 4 with his left hand completely missing. Dave remembers the feeling. "As Crash emerged from the tunnel with one hand completely missing, a horrified moan arose from the crowd. But then, a chant started up in the crowd, raising our spirits as it grew louder with each repetition: 'You don't need no hands, Crash, you don't need no hands!'" Despite only having one hand, Crash held his own, but then in the last second, he lost his other hand and was left standing at the end of the round literally with no hands!

**"The other contestants were amazing. We had MMA fighters, an Olympic champion, and some of the smartest men and women that we've ever met. Amber and I felt truly honored to be competing with them."**

With the Championship and $100,000 on the line, the teams were tied going into the final round, making for an incredibly tense repair period for Team Crash, who needed to get both hands repaired and reattached. "The timer was ticking down," says Dave. "We'd fixed the right hand, but we had less than one minute remaining, and still did not have our left fist reattached because the high pressure air hose that actuated the wrist lock was broken.

In a 'hail mary' moment, I braced myself and held the two broken air hoses together just long enough for Amber to throw the pressure switch, and for Ross to slam the fist into place. In that very second, the horn went off and the officials shouted 'Hands off the robot!'

We backed off, hoping that the hand would stay on ... and it worked! We were so excited, and we could never have done it without Ross. It was perfect teamwork."

Equipped with both hands, Crash battled it out with Steampunk in a very close final round. The tension was thick as Chris Jerico slowly announced the news: "The winner of the fifth round, and the fight itself, with a score of 30 to 27 ... the new Robot Combat League Champion is ... Amber and Dave — Team Crash!" SV

# BarBot 2013 Serves Up Some Intoxicating Entries

By Steven Nelson

Go to **www.servomagazine.com/index.php?/magazine/article/july2013_Nelson** for any additional files and/or downloads associated with this article. You can also discuss this topic at **http://forum.servomagazine.com**.

Host David Calkins

My good friend, Beer2D2 and I made the journey to San Francisco, CA for the Barbot 2013 event that was put on by David Calkins and Simone Davalos. David and Simone are the organizers for ComBots and RoboGames. The Barbot event is actually a fundraiser for RoboGames, and it has been going on for several years now.

The rules are simple: Make a machine that can mix and pour drinks, and serve them to a customer. This has proven to be both an interesting and difficult build challenge. There are many things to consider when designing a machine that can dispense, cool, and serve liquids accurately while keeping them food-safe and tasty, as well.

Since these drinks usually contain ethyl alcohol (which can be a reactive solvent), the hoses, piping, fittings, containers, and valves have to be made of materials that can survive its chemical actions. The various mixes like citrus juices and wines tend to be acidic, and also require components that can handle their pH levels.

To build a beverage-serving robot properly, it takes a fair amount of research time and money to find what will and will not work. The cost of building these systems varies from a few hundred to several thousand dollars. The build times can be as short as one day to five years.

I spoke with several of the participating builders and teams, and asked about their machines and how they came up with their solutions.

# The Archimedes' Fluidic Computer

## Built by Stuart Ferguson

Stuart's machine uses a gravity feed by placing bottles above what he calls a Gerbil valve. It has five bottles with two spirits and three mixes, and it was set up to make six different drinks (of which Mai-Tais and Old Fashioneds proved to be the most popular). When asked about the type of computing system the machine uses, Stuart said, " The machine has no electronics, but I believe it qualifies as a computer. It executes a program (a cardboard recipe card); it uses logic gates (simple mechanical valves); and it uses a comparator (a float scale) to make logic decisions. So, if I had to define the computing hardware I would say: analog, fluidic."

Although mechanical in nature, the machine's recipes were input by inserting paper cards that made contact with the five actuators that controlled the valves that dispensed the liquids. The program timing and the pour amounts can be modified by cutting the cards with a pair of scissors.

During construction, the Gerbil valves were made using an Afinia 3D printer and a custom program called "Modo." Apparently, it took several prototypes to get the home printed valves correct due to the differences in the viscosity of the liquids and variations in the 3D printed components. Future modifications may include a better design for the float assembly and a more intricate stand.

# The Cocktail Engine

## Built by Matthew Dockrey

Matthew's machine uses a gravity feed with custom containers mounted on a steel frame. This system uses an analog control scheme and for this event, it could pour six different drinks. The customer would make their selection using a paper card and a hole punch. The card reader consisted of a series of screws and contacts arranged in a switching array. The card is sandwiched between the contact points, and a handle was manually pulled to make the connections depending if there was a hole or not. The electrical signals (one for each ingredient) are sent to custom boards that use a resistor array to change the output pulse width of a 555 timer.

This signal was sent to a servo that turned a custom chain drive to open a ball valve to dispense the liquids through a hose and into the cup. The custom sprocket sets and mounting plates are made from wood that was designed using Inkscape and then cut using a laser. Matthew mentioned that the most difficult part of the build was getting a reliable contact on the switches for the punch card reader, and that he would like to improve the structure of the valve and servo mounts. He also mentioned that the cost of components will often surprise you when you replicate them many times.

# SantaBarbot

## Built by Zachary Rubin and Andrew Ballinger

This system features a semi circle array of LED illuminated stands containing pumps fed directly from original bottles; a smartphone interface that communicates to a computer via a web server which talks to an Arduino that controls Supersoaker-based electric pumps to actually squirt the spirits; then mixes across about two feet of airspace and into a strategically placed cup in the center of the table.

# Shake

## Built by Reason Bradley, Chris Daniel, and Alexander Rose (Inertia Labs)

Inertia Labs machine uses a $CO_2$ cylinder and an adjustable regulator to pressurize the three bottles containing the liquids that are stored in containers. The machine is designed to pour a Manhattan (Bourbon and Sweet Vermouth).The customer pushes a button that starts the motor, and the pressurized liquids are forced through hoses to the food-grade solenoid valves. The system use a unique analog control that consists of a DC motor that rotates only once per vending cycle. The motor turns a custom disk that contains several custom cam lobes. Each of the cam lobes triggers a different roller blade actuated micro switch for each function.

The steps go something like this as the motor rotates: Trigger the first solenoid, then pour through the first cherub's appendage into the mixing cup until the switch opens; trigger the second solenoid to pour through the second cherub's appendage into the mixing cup until the switch opens; trigger the shaker motor to mix the liquids with (surprisingly) a lot of flair and style and LED illuminated simulated ice until the switch opens; trigger the pour valve and drain the cup through 12 feet of 1/4 inch stainless steel tubing that is surrounded by water based ice to cool and dispense the liquids through the third cherub's appendage and into a nice Martini glass. This analog system is similar to what you might find on a washing machine from the past, before the digital brains took over. It can be difficult to build these systems due to the fabrication of the cams to get the switch/valve/motor timing correct. The structure of the machine is very attractive. It is made from acrylic plastic that was modeled using the 2D Ashlar Graphite CAD program and cut using a laser.

The finish on the laser cuts is impressive. Future improvements may consist of changing from a pressurized system to a peristaltic pump based system, since pressurized systems can be a bit finicky. By the way, the Manhattan was tasty.

# Elixirator

## Built by Bill and Becky Sherman

This machine comes from a past/future that never was — it is constructed in the popular steam-punk fashion from the unique minds of Bill (a.k.a., Doc Hadacoff) and Becky. The Elixirator is able to pour 10 different elixirs or tonics to cure anything that ails you. The various spirits and secret ingredients are contained in sparkling cider bottles and pressurized using an aquatic pump. Motorvation and intelligence is provided with a PICAXE microcontroller using the Basic programing language that is common from its time period. Custom electronics were created by the doctor to control the pumps and valves. Plans for the machine were drawn out using ExpressPCB and a spiral bound notebook.

The user interface consists of three illuminated buttons, a Nixie tube, plasma globe, and a Tritium meter. One should always keep an eye on those pesky stray neutron/proton radiation levels when mixing elixirs. The cabinet is made mostly from hand stained wood adorned with various brass and copper structures that were derived from that rare element called Obtainium. I asked the good doctor what he learned from this experiment and he said," Design the project in your mind and on paper before cutting any wood or buying stuff. Think if you have a possible answer to every design problem that may come up. Once you have a clear understanding of what you are building, start building. Don't rush your creativity; the answers will come to you as you build. A good neat build will create pride and a sense of accomplishment with your own work. Others will respect what you did as an extension of your abilities."

He also mentioned that when he returns to the past/future, he may look into experimenting with peristaltic pumps and the motor driven pumps derived from Supersoakers from the future/past. I did enjoy sampling his elixirs/tonics. It was an inspiring experience.

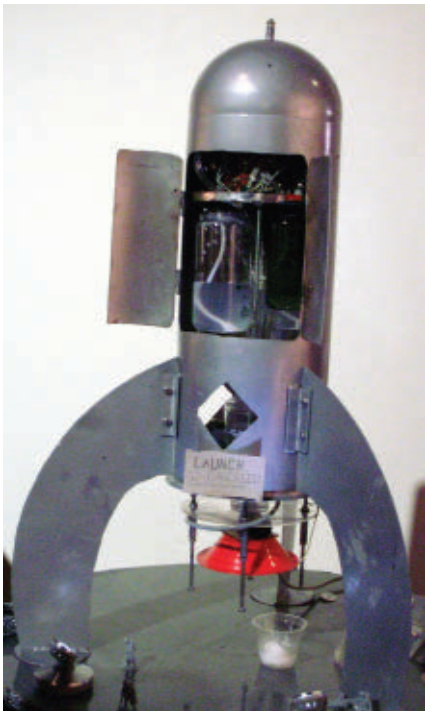
# PachencoBot

## Built by Ray Sykes, Sean Cusack, and Paul Walker

This machine uses a Daido GT Time Pachinko machine as its user interface. The Pachinko machine was modified by connecting an Arduino Mega 2560 microcontroller to one of the goal's optical switches that is normally read by the game's computer. The operation goes something like this: The customer takes a half of a cup of steel ball bearings and pours then into the machine's hopper. Then, a rotary control is turned to start the game's feed wheel turning. The rotary controls also change the speed of the feed wheel, which changes where the balls enter the top of the playfield that is filled with patterns of pins that cause the balls to take different paths. Only one goal would trigger the Arduino, which controlled a servo that pulled a stiff wire/rod that opened or closed the valve on the bottle of spirits.

In testing, I found that it really wasn't that difficult to find the sweet spot and correct motor speed to get more than one win/shot when using this machine. I got four shots of straight Tequila on my first try. I saw one girl get nine. This machine became rather infamous as the night went on, and generated several trips by the winners to the actual human controlled bar operated by Victoria and Flash for some mix. Ray mentioned that the main building challenge was," A little hiccup when we programmed it as the servos did not respond to commands how we thought they would in the Arduino servo library. Full turn servos respond entirely differently than 180 degree servos, and we had to make the program quite a bit more complicated to accommodate the hardware we had." Ray also told me that "It's possible to get reprimanded by the human bartenders for having a bot that's too generous on the Tequila."

Future upgrades may include replacing some of the hot glue and dangling wires with actual hardware so that it's easier to take places.



# Cosmobot

## Built by Samuel Coniglio, Ken Mochel, and Joe Phillips

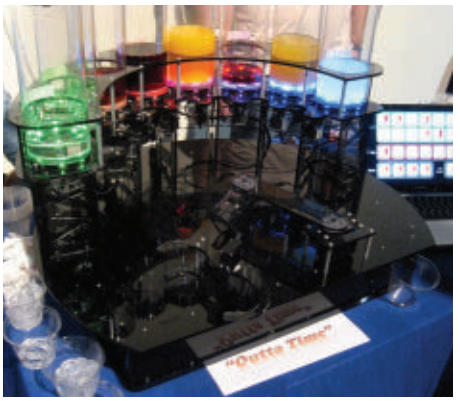
This machine is straight out of a 1950's sci-fi thriller. Its structure is a stainless steel rocket ship that even Buck Rogers would be proud of. The system pours three different hybrid rocket fuels: Cosmopolitan, Cape Cod, and Kamikaze. The fuel tanks (Pepsi bottles) are pressurized using an aquatic 24 VDC air pump forcing the spirits and mixes to the 12 VDC electric solenoid valves. A digital control room contains an Arduino Duemilanove, with solid-state relays and a power supply. The software is written in the Processing language. There is a toggle switch used by the technicians to purge or pour the fuels to prevent explosions, a dial for selecting the different fuel mixtures, and a lighted big red button that allows patrons to activate the rocket.

In operation, the pressurized liquids are forced into the reaction/cooling chamber and the pass-through frozen carbon dioxide (dry ice). An instantaneous reaction occurs as the $CO_2$ converts directly from a solid to a gas and cools the fuel mixture to safe temperature levels as they pass through the rocket nozzle in a liquid form to fill the glass below. Copious amounts of white smoke are produced during this reaction, and it is enhanced with LED lighting, as well. A small piece of frozen $CO_2$ is added to the patron's glass for extra cooling of the rocket fuel/drink.

Samuel mentioned that future upgrades may include, "A mechanical seal system for the tubing. No more glues and epoxies. Replacing the Pepsi bottles. Possibly relocate all ingredients outside of the bot. A new mixing system. A crawler bot to serve the drink. Add another dial to increase the quantity of the ingredients." This interplanetary adventure leads to a smoking good show.

# Outta Time

## Built by Paul Ventimiglia and Marc DeVidts




The Outta Time system was designed in CAD and its entire structure was CNC laser-cut from acrylic plastic — again with very clean cuts and edges. The pumping action for the spirits and mixers uses the pressure timed method by pressurizing the eight LED illuminated acrylic containers using regulated $CO_2$ gas, and vending the liquids with a solenoid actuated valve. The electronics are controlled using an Arduino Mega 2560 microcontroller that communicates with a PC displaying menus and a touch pad activated point and click interface. The system uses a unique two axis servo powered robotic arm with a cup holder and servo powered gripper.

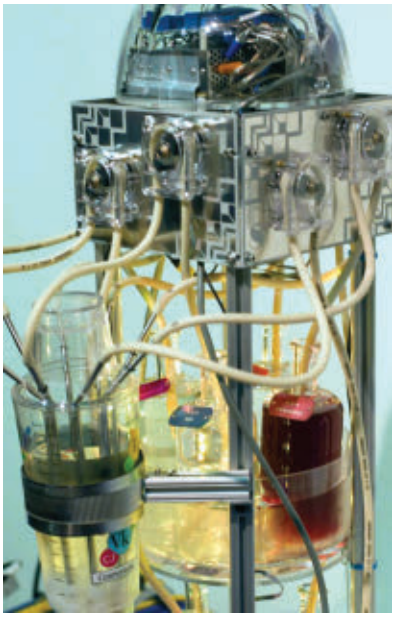
During operation, the patron places a cup in the robotic arm's holder. Then, they select a drink from the computer screen. The cup holder closes its gripper and slides the cup using the robotic arm under each of the containers necessary for that recipe. The solenoid valve opens on the container and the liquid flows for the proper amount of time. Then, the arm moves on until all of the ingredients are poured. The arm then returns the cup to its home position and the patron takes their drink.

The drink menu listed 27 recipes that were renamed with amusing references to start-up, programming/hardware shipping issues, references to combat robotic machines and teams, and the infamous David Calkins drink recipe that contained Whiskey, Sour, Sour, Sour. This drink selection would just say NO and return an empty cup. That selection generated much hilarity in the robot builder community.

# Thinbot

## *from the Drinks Advanced Research Program Agency*

## Built by Kevin Roche and Andrew Trembley



*In homage to the "Thin Man" movies, where Nick and Nora Charles solve murders while consuming Martinis by the pitcher.*

The Thinbot system uses peristaltic pumps to deliver the spirits and mixes. For the event, it was programmed to provide 16 different recipes, plus it had a custom build-your-own-cocktail option that allowed the patrons to design their own drinks. The machine was designed using the Alibre CAD software. The structure of the system was machined and fabricated by hand. Thinbot is controlled using an Arduino Mega 2560 microcontroller with an AdaFruit touchscreen/microSD shield. It is programmed using the standard Arduino Processing/C++ language. Electronic control is provided by a TTL-level relay board that powers the peristaltic pumps and lights. The user interface is provided by a small control box containing the touchscreen.

During operation, the Arduino loads the drink recipe information, pump speeds, and timing from the SD memory card. The touchscreen provides patrons with four drink recipes per page, plus forward and back buttons to choose other drink options. The patron is given the choice to commit to the pour or not. A photo of the drink is displayed after the selection is made. As the drink pours, a status bar indicates what liquid is vending.

After the pour, the lighting changes, then a picture of the actor William Powell as Nick Charles toasts the patron and a small bell is rung to indicate "Order Up!" Another feature of the Thinbot system is the surprise function that will pour a random drink from the list of recipes. The liquids are cooled by running the output lines through an ice water bath that recirculates, and also provides a continuous LED color cycled enhanced fountain effect when the system is idle. That's a nice touch.

Kevin mentioned that some of the design challenges involved acquiring reliable peristaltic pumps. Thinbot uses custom pumps built by the Anko Pump company using USDA approved food-grade technology and Norprene tubing. Also, the wiring and plumbing is designed to allow for easy assembly/disassembly for transport to events. Kevin commented that a larger drain for the fountain and an upgrade to the cooling system is being considered.

# Bartendro

## Built by Pierre Michael, Robert Kaye, and Erin Berman

Bartendro is the result of almost five years of development; the first version was built in 2009. This team brought two versions of their system: Bartendro 7 and Bartendro 15. At this year's event, Bartendro 7 was capable of pouring 10 different drinks. Its bigger brother (Bartendro 15) could pour a whopping 42 different drinks!

The system is capable of many more drink combinations but they kept the menus short for this event. The Bartendro system uses peristaltic pumps to pull the liquids up through tubing and into the pumping cavity. A system of rotating cams and rollers squeeze the tubing inside of the circular pump's cavity. By squeezing the tubing, the liquid is pushed out of the discharge side. As the roller passes the compressed side of the tubing, the now uncompressed tubing behind the roller returns to its natural state and draws more fluid from the container of spirits or mixes. Since the liquid is only in contact with the inside of the tubing, it remains very sanitary compared to other pumping methods. This action can be controlled by starting and stopping the drive motor to control the amounts that are vended. The system was designed using Eagle CAD and SolidWorks. This allows the team to send out some CAD files for parts to be made by vendors, and also allows them to create parts with their CNC milling machine in their shop. The Bartendro system is digitally controlled using a Raspberry Pi that communicates to separate custom Arduino-based controller/driver boards that each pump is mounted to.

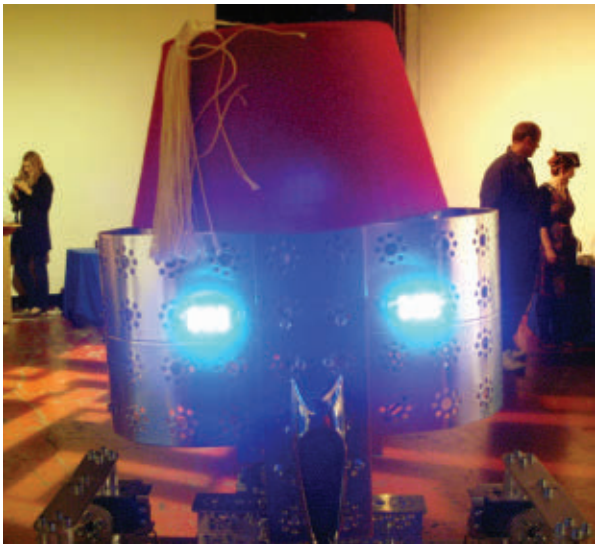
The driver board also contains several LEDs that illuminate the see-through pumps for a bit of flair.

The Raspberry Pi is programmed using the Python language and also a web server. The Arduinos are programmed using the C language. The user interface can be accessed through any device that has a web browser using an access point called Bartendo. A password is needed to actually pour a drink and to prevent accidents. Basically, the patron sees the drink menu, selects their drink from the scrolling menu, and then a second page allows them to adjust the size, strength, and sweetness of their choice.

I asked Pierre if there were any modifications to the system he would like to make and he said, "Yes, we really want to be able to dispense carbonated liquids flawlessly. We're not there yet. Also, ice dispensing would be really nice. By making things open source, we're hoping others will contribute to make our bots even better."

Pierre also mentioned, "Making drink bots is really challenging. From the ease of use and maintenance, to the complicated chemistry of tubing and other materials used. We want to make a safe, sanitary, reliable, and low cost product, and the combination of those things — while eventually achievable — requires research and patience. If you put enough resources on it, almost anything can be done."

The Bartendro system is an open source project and it does have a Kickstarter page in the hopes of making it available to builders in a kit form.



BarBots has definitely evolved over the years into a very different event from others I have attended and built for.

It has a wonderful mixture of art, complex technology, humor, silliness, and, of course, beverages. It proves that geeks know how to have fun and social interaction with their toys. Building for this event is very challenging and rewarding. As a builder, you have to learn a lot about hardware and software to actually pour liquids correctly with repeatability. I don't think anyone has figured out how to vend ice accurately yet, and that is part of the fun. Simone told me, "Barbots is a fun night of drinking for science!" SV

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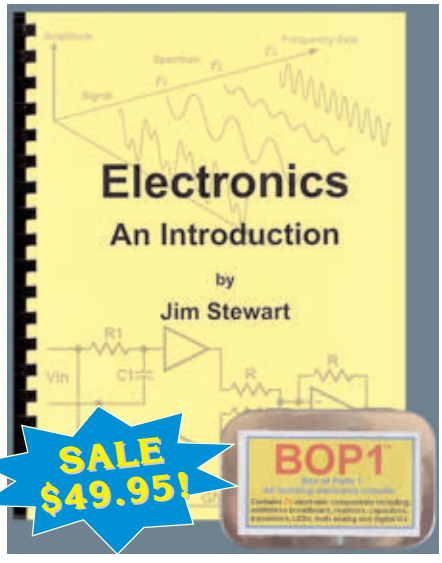


## ROBOTICS

### Robot Builder's Bonanza, Fourth Edition

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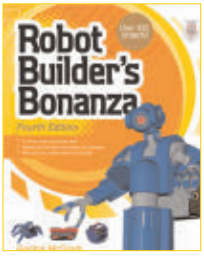


*Robot Builder's Bonanza, Fourth Edition* includes step-by-step plans for a number of motorized platforms. The book is described as a compendium of robotics topics, containing more than 100 projects, including 10 robot designs new to the fourth edition. These modular robots are low cost, and are made to be reproduced by readers with no training in mechanical construction.

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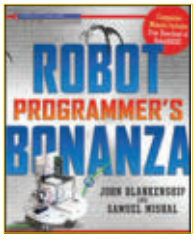


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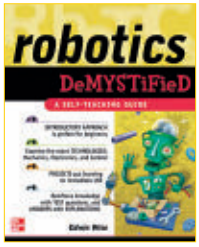


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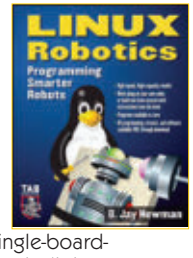
## Linux Robotics

by D. Jay Newman



If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need.

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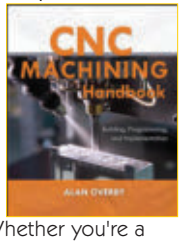
by Alan Overby



The *CNC Machining Handbook* describes the steps involved in building a CNC machine and successfully implementing it in a real world application. Helpful photos and illustrations are featured throughout. Whether you're a student, hobbyist, or business owner looking to move from a manual manufacturing process to the accuracy and repeatability of what CNC has to offer, you'll benefit from the in-depth information in this comprehensive resource. **$34.95**

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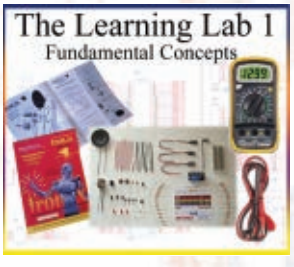


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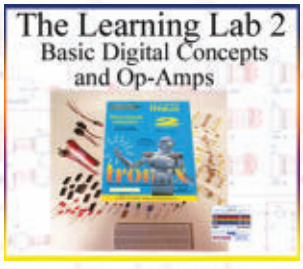


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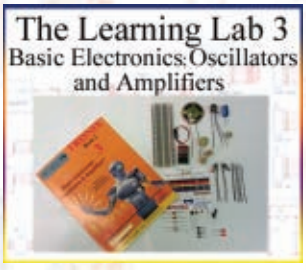


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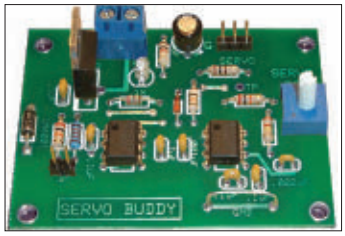


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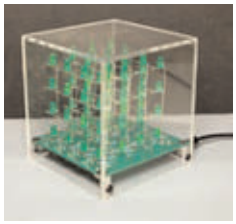

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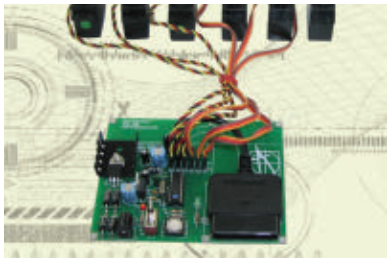

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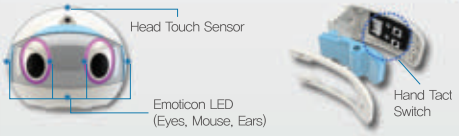


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| Max. Speed | 0.164s/60° @14.8V | | 0.162s/60° @14.8V | | 0.147s/60° @7.4V | 0.166s/60° @7.4V |
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| Motor | Premium FAULHABER Coreless DC | | | | Coreless DC | Metal Brush Cored DC |
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# 3D Printers

*This month:*

Part 1. Introduction into 3D Printers
Part 2. Assembly Highlights
**Part 3. Software and Configuration**
Part 4. Tuning
Part 5. Upgrades
Part 6. Conclusion

by Michael Simpson

Go to **www.servomagazine.com/index.php?/magazine/article/july2013_Simpson** for any additional files and/or downloads associated with this article. You can also discuss this topic at **http://forum.servomagazine.com**.

***Originally, I was going to go over the software that is available for the various 3D printers. However, I want to change things up a little and talk about the first prints from each printer. I want to talk about what it took to get from a ready-for-action printer to a first print.***

## The First Layer

Let's talk about some things that affect all extrusion-based 3D printers: the first layer. While there are many places things can go wrong while printing, the first layer sets the pace for the entire print. If it goes wrong, then the print will suffer. The most common reason for first layer failure is adhesion problems. **Figure 1** shows what happens when the extruded plastic does not stick to the bed. If you frequently surf the forums, you will quickly find that "Print Not Sticking to Bed" is very high on the list of common print problems. The following factors are the most common ones encountered that can affect first layer adhesion to the bed: bed material; bed temperature; printing speed; printing height; level bed; filament material; and part size. The print in **Figure 2** failed because the bed was not getting hot enough for the bed material. So, what works?

Here are some of the settings I use.

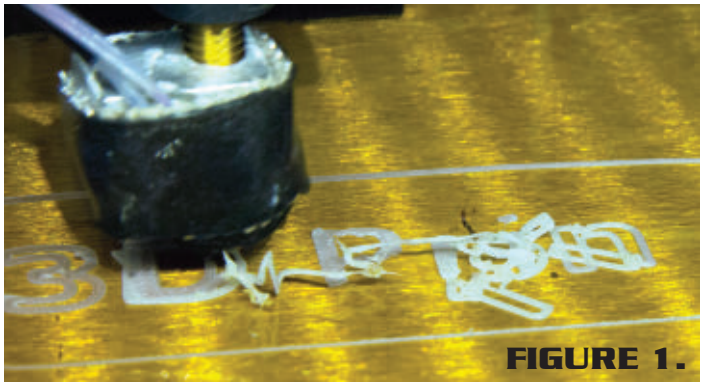


FIGURE 1.

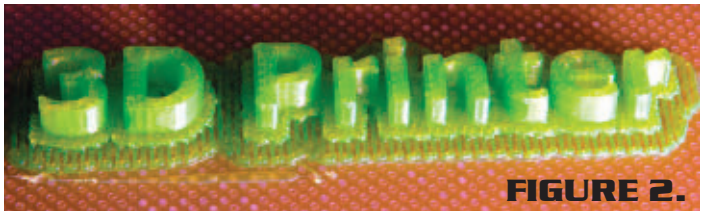



FIGURE 2.

### ABS

Print on quality Kapton tape with the bed set to 100-120°C. Depending on the ABS used, the extruder temperature is set to 220-240°C. I set the first layer print speed to 10-20 mm/s. My first layer height is between .2 and .3 mm. The bed needs to be level with the print head. There needs to be about .1 mm between the nozzle and the bed when the Z axis is at zero.

### PLA

I set PLA the same as ABS, except I print on glass with the bed temperature set to between 65-75°C. Extruder temperature is set between 180-220°C.

## Too Hot to Handle

Okay. You have good adhesion, but after about 10 layers the print starts to go wrong. The layers start to droop or you start to see gaps. This is a sign that heat is building up in the print. The key to identifying this problem is that the

FIGURE 3.

FIGURE 4.

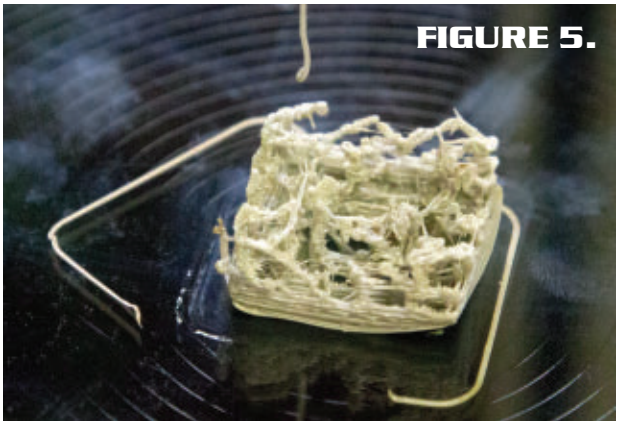


FIGURE 5.

first few layers print very well. Once the heat builds up, the layer quality will start to degrade. You want some residual heat on the layer below the currently extruding layer. This helps the two layers bond. If the heat of the last layer is not cooled at least a little, each layer will continue to build up heat until the layer starts to melt and sag.

There are two ways to solve this heat build-up. The first is to slow down the printing so that the last layer can cool. The other way is to blow a small amount of air on the print as it is printed.

Take a look at the two parts in **Figure 3**. The part on the left was printed very fast with no air blowing on it. The heat built up very fast and it created a layer meltdown. The part on the right was printed at the same speed, but a small amount of air was blown on the part using a fan manifold. While not perfect, the air did help to improve the printing process. Slowing the print down just a bit would also help.

Because of its low melting point, PLA tends to suffer more from heat build-up than ABS. Note that some of the printers have controller-controlled fans for cooling the part.

## Retraction Action

Retraction is an important task the extruder must perform to create accurate prints. Retraction takes place when the extruder must stop extruding filament in order to move to a different location on the part. The extruder will retract the filament a small amount to relieve the pressure in the nozzle and thus stops the extrusion process. This is a delicate process, and the speed and amount the filament retracts affects the print.

The parts in **Figure 4** shows what happens when the retraction is not set up properly.

Most 3D printer manufacturers provide settings for the proper retraction, however, it may be necessary to tweak the settings yourself.

## Extruders One and All

Extruders are the heart of extrusion-based 3D printing, so when your extruder starts acting up, then all bets are off. The print shown in **Figure 5** was caused by an extruder that had a tension bearing that was too loose.

When looking to purchase a 3D printer, keep an eye on the extruder. An extruder that is overly complicated will give you no end of problems. The extruder shown in **Figure 6** is the extruder that comes with the Rostock Max. Too many gears and too many moving parts!

I prefer direct drive extruders. When built properly and regularly maintained, these extruders perform flawlessly. The extruder shown in **Figure 7** is the direct drive extruder used in the Solidoodle 2 and Solidoodle 3 3D printers.

Here is what I look for in a extruder: direct drive; spring loaded tensioner; easy access for cleanup; cooling fan for cold-end to hot-end transition; and cooling fan for stepper motor.

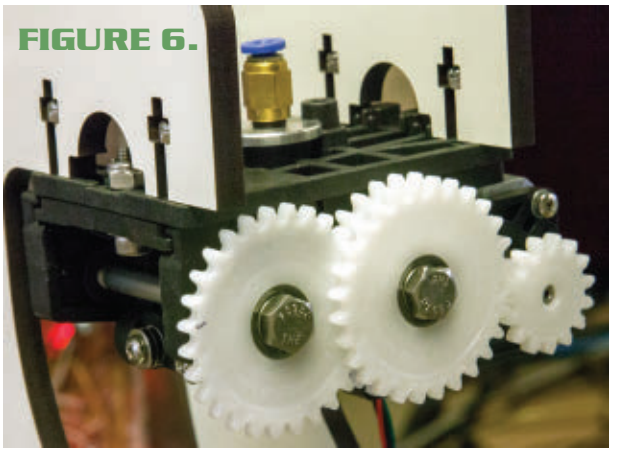


FIGURE 6.

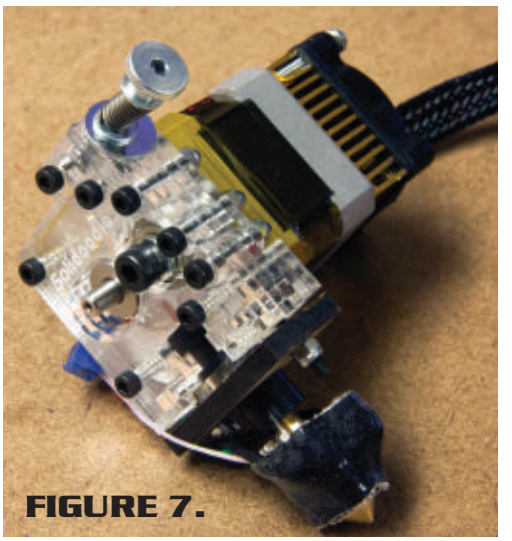
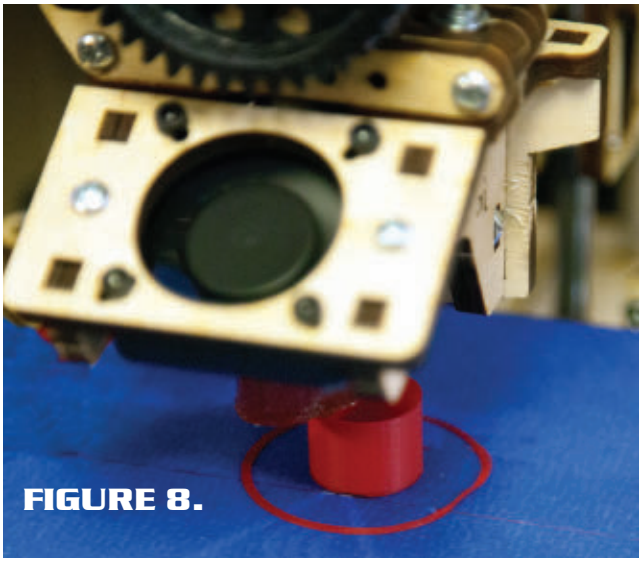


FIGURE 7.



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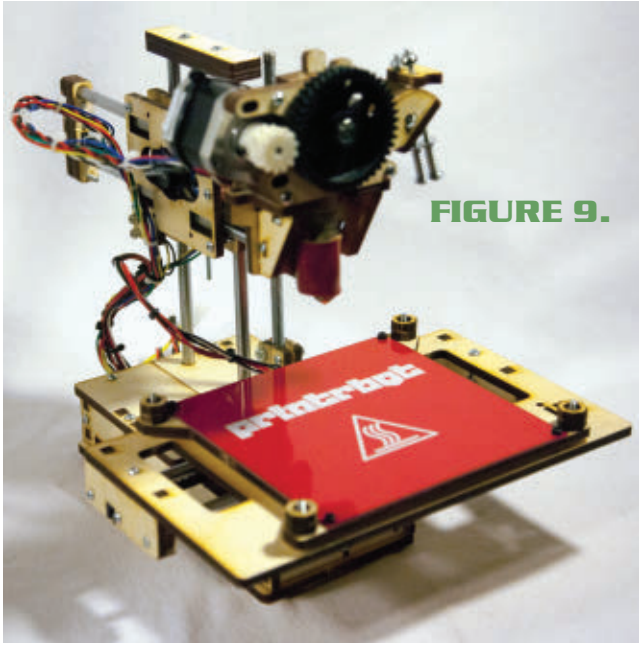

FIGURE 9.

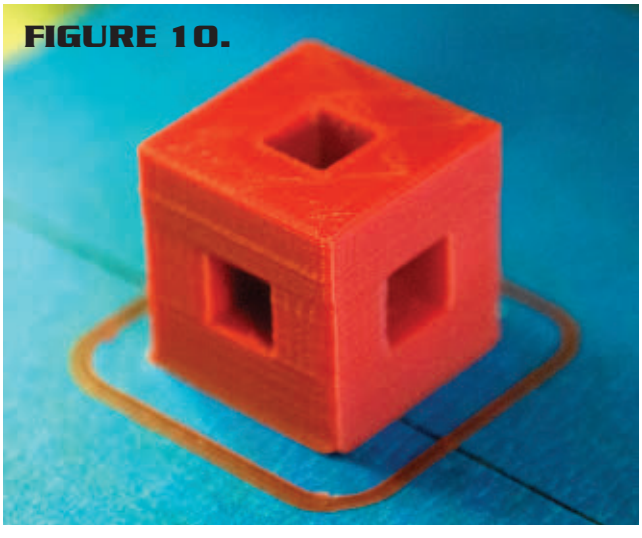

FIGURE 10.

## First Prints

Our first prints are important because they give us an indication as to how accurately we or the manufacturer has assembled and configured the machine. Bar any of the problems mentioned previously, we should get a print that at least resembles the object we are trying to create. I like to keep my first prints so I can go back later and compare them as I calibrate, tune, and gain experience with my printer.

### ABS vs. PLA

The two most common filaments that are used with extrusion-based printers are ABS and PLA. Both have advantages and disadvantages. I prefer to start with ABS when testing my machine for the first time. The main disadvantage of ABS is that it tends to warp when doing large prints. It is, however, more forgiving than PLA so I always recommend it for first timers.

### Printrbot Jr.

Before getting started, there are two upgrades that are a must for the Printrbot Jr. in order to create quality prints. The first is what I call the extrusion fan shown in **Figure 8**. The controller used in the Printrbot Jr. has a hookup for this fan so it's a no-brainer. This fan — when used with care — will keep heat from building up when printing small parts. Use it sparingly as it can cause the prints to cool too fast and magnify warping. Recently, Printrbot has added this fan as a stock item to the Printrbot Jr.

The next upgrade is a heated bed. A heated bed does two things. First, it helps keep ABS from warping as the part is being formed. Second, it helps with bed adhesion for both PLA and ABS. Again, the Printrbot controller has a hookup for this accessory (see **Figure 9**).

The first print I perform on all my machines is the hollow cube. This object can be found on Thingiverse at **www.thingiverse.com/thing:5011**. (Thingiverse is a website for sharing files of printable objects.)

When you print an object that has a hole in it like the cube shown in **Figure 10**, it has to do two important maneuvers. First, it must stop and start the extrusion process precisely in order to not create little blobs or voids on the edges. This is done with filament retraction. Second, it must bridge the gap at the top of the hole. The filament that extends across this gap is called a bridge.

Small holes are easier to bridge than large ones. Most software can produce what is called supports. These supports help close the gap so you don't get sagging of the bridge. The support material is designed to be easily removed, so this can be a hit and miss process depending on the part.

The Printrbot printed a very respectable cube for its first print (refer again to **Figure 10**). I got very little sagging and the finish was well done for a printer that has not been fine-tuned.

If you notice the slight flaring of the bottom layer of the print, this is an indication that the starting layer height was a little too low.

Take a close look at the loop around the object. This is called a skirt, and is an option provided by the slicing software. By printing a skirt around the object on the first layer, the extruder is able to properly prep the nozzle before the print starts. The skirt also gives an indication of how well your nozzle is distanced from your print surface.

In this case, it is very flat, indicating that the nozzle is too close to the bed. If the top of the skirt is rounded, then the nozzle is too far away from the print surface. The perfect distance is somewhere between these two positions. I like a small bead with a flat top. Note that if the nozzle is too far away from the print surface, it will not provide enough force for the extruded plastic to adhere to the bed.

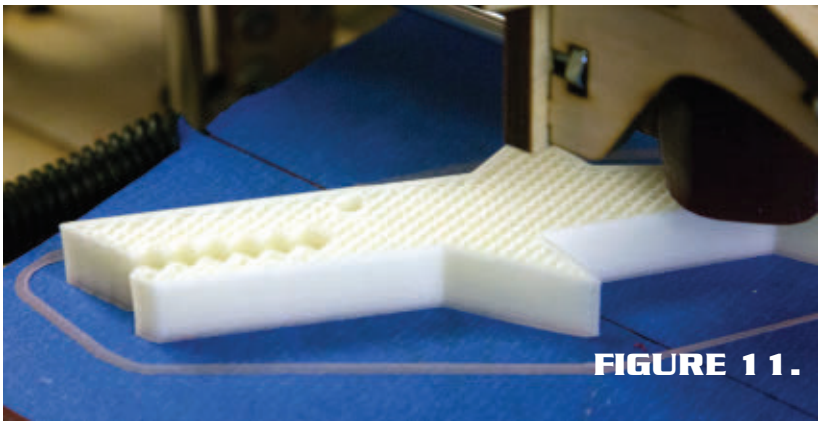
FIGURE 11.

Notice that I am printing on blue painter's tape. Blue painter's tape is not the end-all printing surface. It can be hit and miss. Personally, I prefer Kapton tape heated to between 90°C and 120°C.

I did a little tuning of the printer before I started my second print. The print shown in **Figure 11** is Mr. Jaws. It's a potato chip bag clamp and can also be obtained from **www.thingiverse.com/thing:14702**.

Notice the inside portion of the print. This is called the infill. The lines of extrusion that make up the outside of the print are called perimeters. Perimeters surround holes or open areas inside the part, as well. The infill can be solid, but in most cases, it is some percentage less than solid. In this instance, I have the infill pattern set to honeycomb at 30%. The print turned out very well. I still had a small amount of flaring on the bottom layer, but this can be corrected by adjusting the Z axis limit switch or by changing a setting in the software.

All in all, the Printrbot Jr. printed very well on its first couple of prints. Bed height was a bit problematic as the Z axis limit switch was not consistent, but some of this can also be attributed to the overall lack of machine rigidity.

I initially had problems with the Rostock Max but was able to fix most of them; others I am still working on. You can read about them on my website at **www.kronosrobotics.com**.

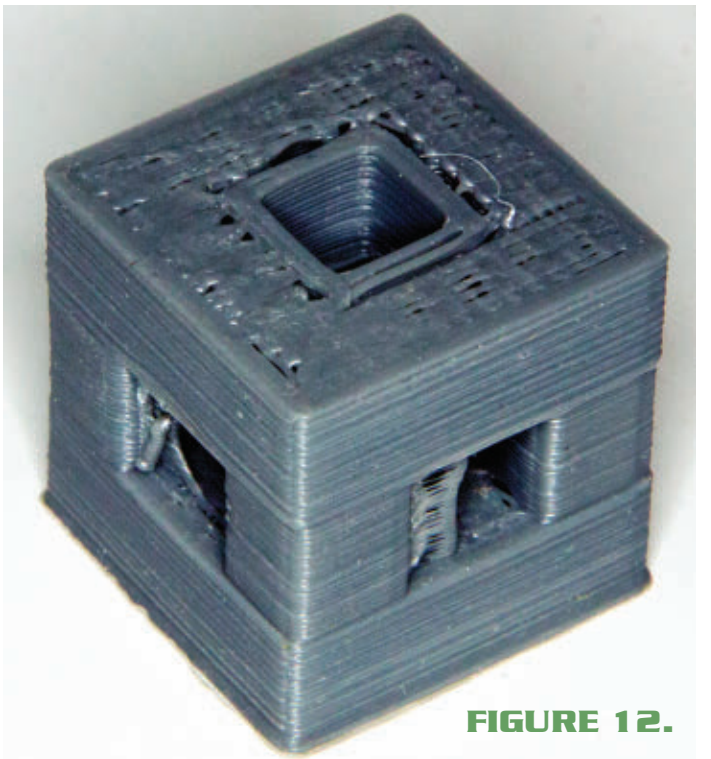
FIGURE 12.

## Rostock Max

As a delta printer, the Rostock Max required more setup. Instead of adjusting the bed, each of the limit switches must be tweaked until the nozzle remains at a constant distance from the bed no matter what its X or Y position. While it's not an impossible task, it does take longer than on all the other machines

The cube shown in **Figure 12** was not the first one I printed with the Rostock Max, but it was one of the best I could get.

Mr. Jaws in **Figure 13** came out a little better, but it was evident that the printer was having retraction issues.

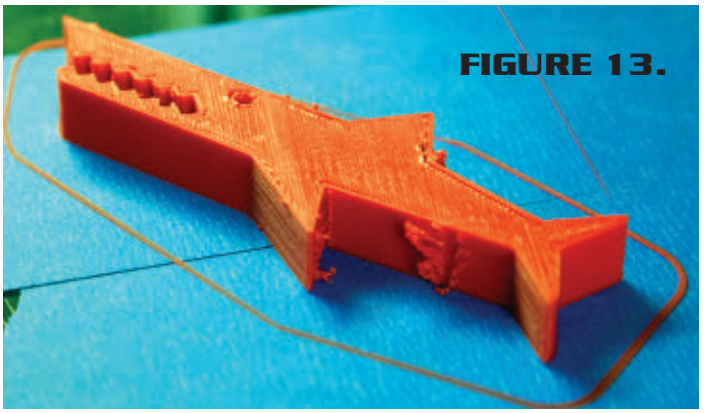
FIGURE 13.

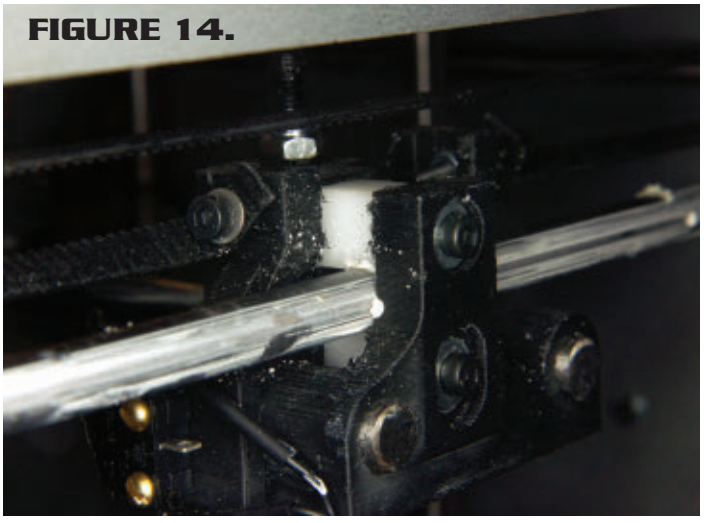
FIGURE 14.

## Solidoodle 2

The Solidoodle 2 was the first fully assembled 3D printer I purchased. I had assumed it would come ready to print. After a few test prints, I realized I had some tuning to do. The Solidoodle 2 utilizes a brass bushing on the left carriage and an adjustable plastic bushing on the right carriage (shown in **Figure 14**). On my Solidoodle 2, this bushing had a 1/4" up/down play in it. Just under the extruder, the Solidoodle 2 utilizes a brass bushing on the front rail. On the rear rail there is a plastic bushing (shown in **Figure 15**). Again, this bushing was so loose that the Solidoodle 2 would rattle as it printed.

After tightening both plastic bushings and adding some white lithium grease, I printed the cube shown in **Figure 16**. Other than a little drooping in the bridging and a flared first layer, the print came out perfect. Next, I printed the Mr. Jaws part shown in **Figure 17**. Again, I was very pleased with the print. However, if you look close at the head and tail you can see that it warped slightly.

The warping of the part is caused by lack of adhesion to the bed. ABS shrinks as it cools, so the bed must be kept nice and hot during the printing process. As I stated before, blue tape can be unpredictable. The Solidoodle 2 comes with a sheet of 5 mil Kapton stuck to the heated aluminum bed, but I could not get the ABS filament to stick to the Kapton no matter what I tried. The result was the print shown previously in **Figure 2**.

I did some research and found out that not all Kapton tape is created equal. Kapton is actually the registered trade mark for a polyimide polymer made by DuPont. Some of the tape — especially the imports — may not even be real Kapton. I have several rolls of Kapton tape that I purchased when I started my foray into 3D printing. I put a few strips of Kapton tape down over the original Kapton that came with the printer and printed the same exact print from **Figure 2**. The result was outstanding. The ABS stuck like glue, as shown in **Figure 18**.

The Solidoodle is a very inexpensive fully assembled

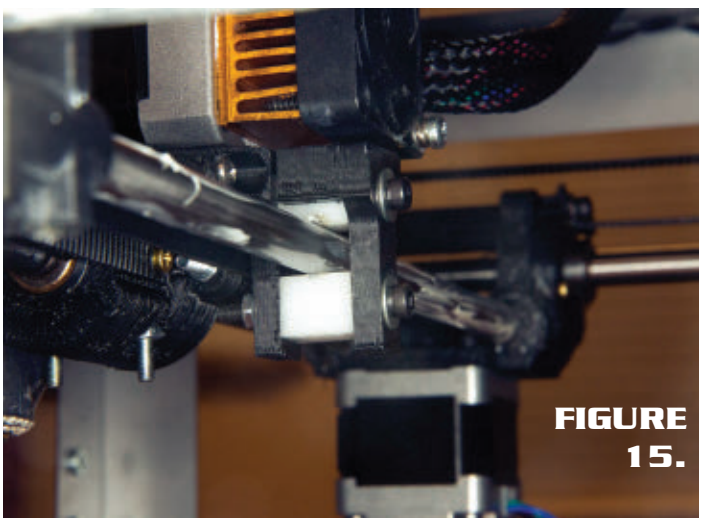
FIGURE 15.

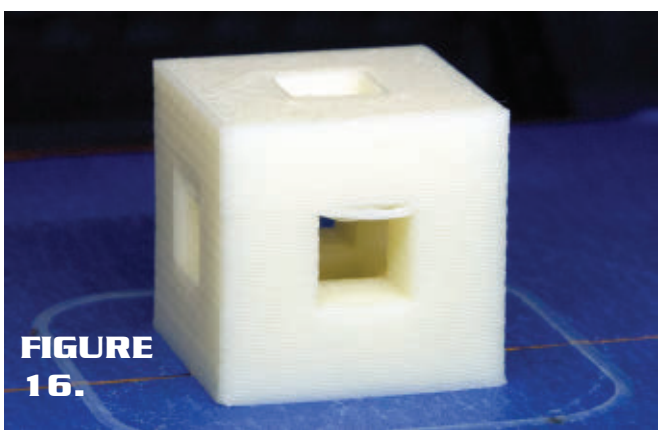
FIGURE 16.

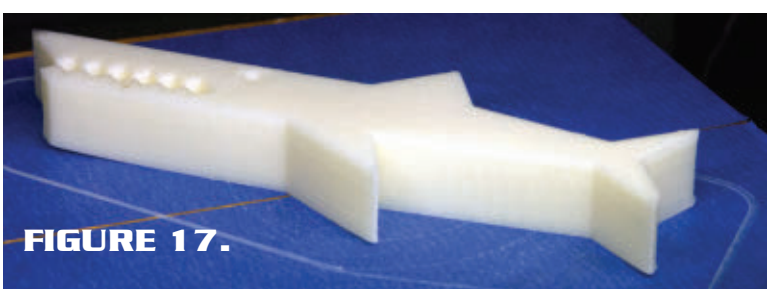
FIGURE 17.

FIGURE 18.

printer. Of course, they had to cut corners to produce a printer at this price, and while tuning the printer will help you produce good prints, my concern is that over time, the plastic bushings are going to require more attention.

## Afinia

The Afinia is my second fully assembled printer. This printer is as close to plug-and-play as it gets. All the other printers are open source printers and use the same software. The Afinia, on the other hand, is a closed source printer. It utilizes its own software. I could go on and on talking about the Afinia, but the proof is in the prints.

One of the issues I have with the Afinia software is the inability to turn off supports. This means no matter how small the hole or opening, the Afinia will create support structures. While these structures can easily be removed, they can present problems with some prints. **Figure 19** shows the hollow cube print. The supports were added to all the holes in the four sides of the cube. **Figure 20** shows the cube with the supports removed. While the print requires more post cleanup, it did turn out very well.

While I printed the Mr. Jaws several times on the Afinia, I wanted to show you something a little more useful. No other printer I have tested to date can accurately print the GT2 gears shown in **Figure 21**. Not so with the Afinia. The gears have small pockets on each side that hold #4 nuts. This allows me to insert two #4 machines screws to hold the gear in place. The shaft opening is 5 mm so the gear fits over the NEMA 17 stepper shown in **Figure 22**. The gears drive a GT2 pulley and work perfectly.

Overall, the Afinia printer is what all other 3D printers should be judged against. Its success can be attributed to its closed source software. The raft and support generation is superior to all software I have used to date. This printer only has a build area of 5" x 5" x "5, and at a price of $1,600, this small print area is something you must consider.

While the Afinia's software contributes to its success, it is not without some issues. For one, its lack of temperature control inhibits your ability to utilize third party filament. The software is tuned for the Afinia premium ABS filament. This filament extrudes between 260°C and 275°C. This is much too hot for standard ABS filament. While it will work, both rafts and support structures are bonded too well to remove. Your only option is to use a third party switch to trick the machine into using a lower temperature.

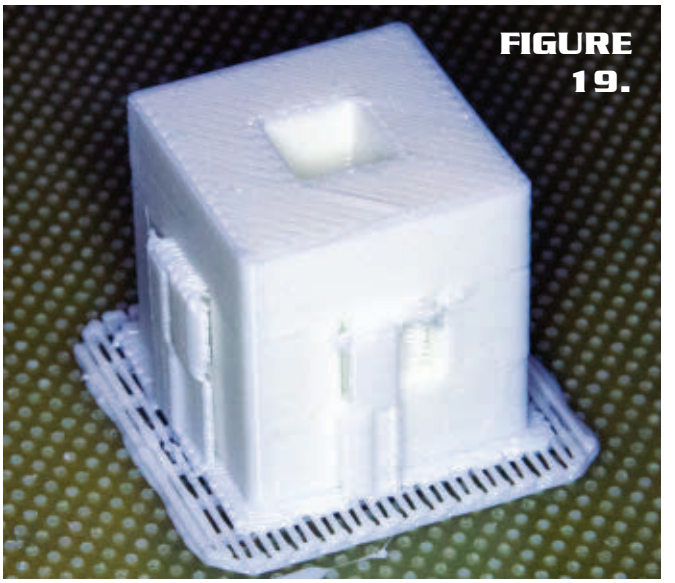
FIGURE 19.

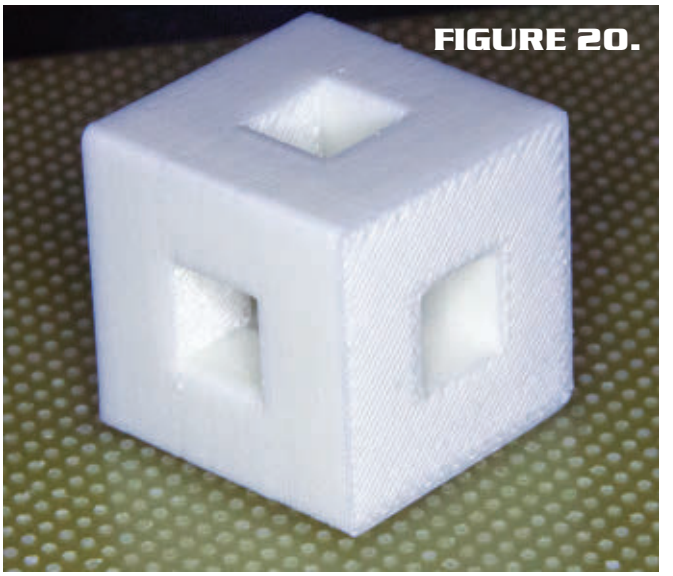
FIGURE 20.

FIGURE 21.

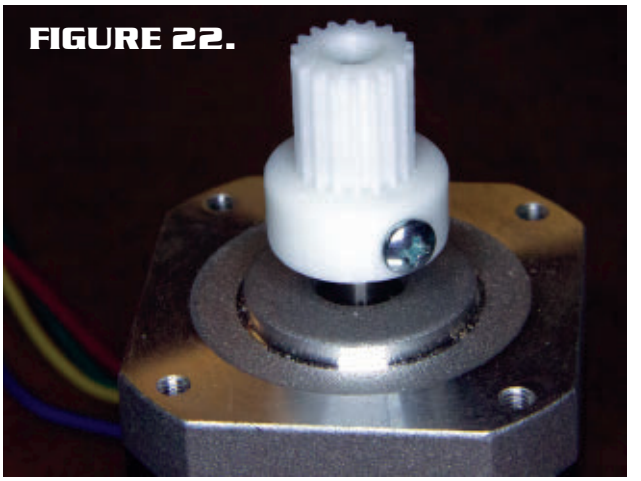
FIGURE 22.

## Conclusion

Before I close, I want to talk a little about ABS. I used ABS filament for all my test prints because it's easier to use than PLA. It does suffer from one major shortcoming, however: it shrinks when it cools. This causes it to warp as you are creating a part. The warping is controllable when printing smaller parts, but on larger parts the warping can be severe. To remedy this warping problem, the Afinia uses a perfboard and a raft. Even this does not work at times. **Figure 23** shows how the warping has caused the perfboard to be pulled up from the bed. This will cause the part to be distorted as it is created.

You can't use binder clips on the right and left sides of the bed, as they will not clear the frame. Shown in **Figure 24**, I created some small clips that hold the perfboard in place as it prints. I spent many hours trying to get this part to print reliably. By just adding the clips, I was able to solve the problem.

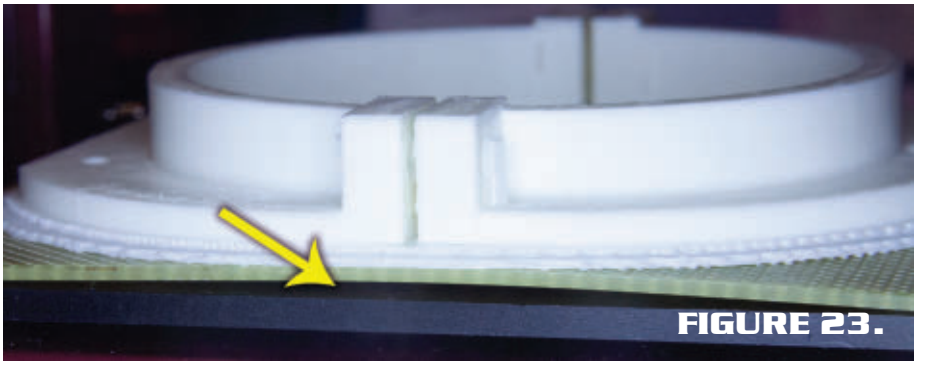

FIGURE 23.

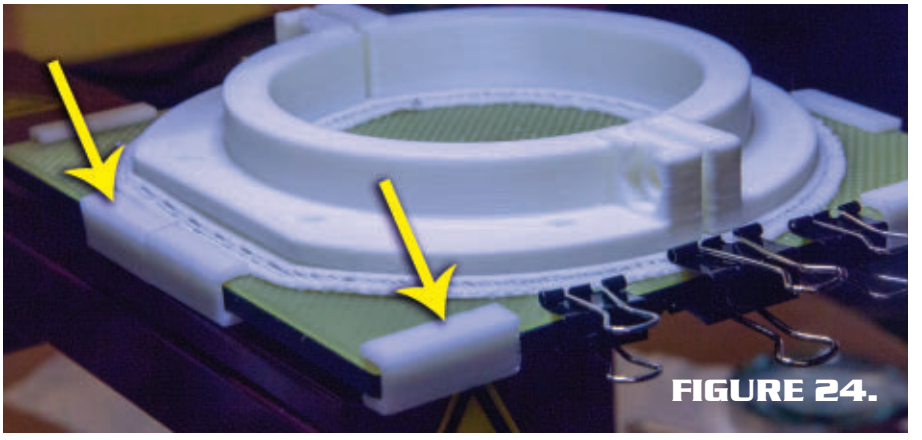

FIGURE 24.

## Next Month

Next month, I will cover the various software packages we use to control these little gems. In addition, I will be adding a fifth printer to my lineup. The printer shown in **Figure 25** is a MakerGear M2. I purchased it in kit form, so I can fully understand the inner workings. It has a moving platform much like that of the Afina, but with a much larger build platform.

Please be sure to post any questions on the *SERVO Magazine* forums. I will also be posting additional information on my website at **www.kronosrobotics.com/3d**.

## Final Thoughts

These are only my initial prints. I still have a lot of printing to do. I will put these printers through their paces as the series continues.

When this 3D printer series is finished, I plan on doing a 3D "battle bot" series where I will show you how to build a robot with parts totally from your 3D printer. SV

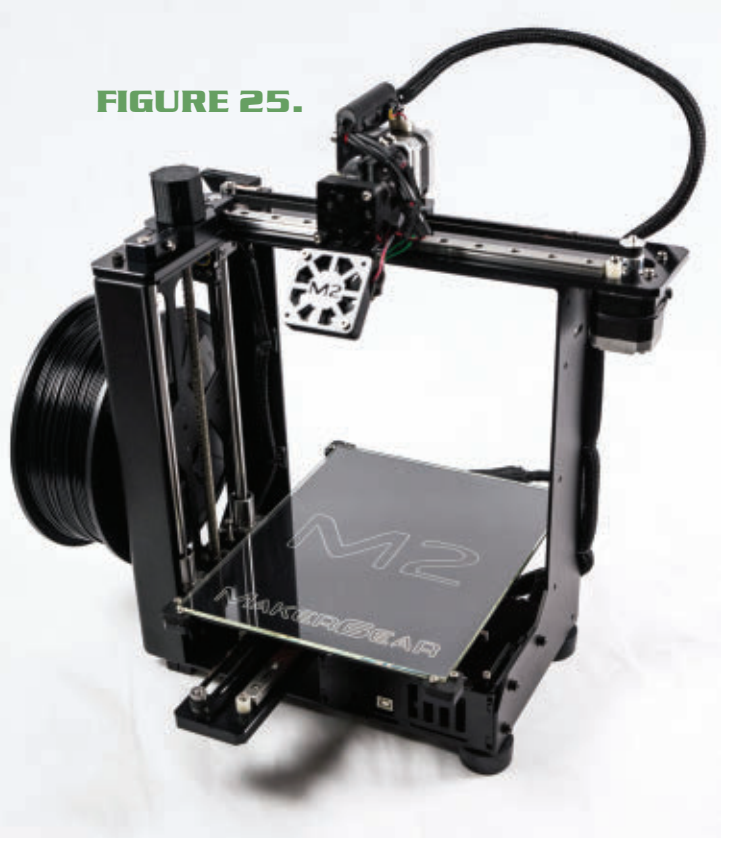


FIGURE 25.

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# Then and NOW

# Robots to Serve Man

by Tom Carroll

**In the past few months, I've discussed many ways that robots are being used by mankind, or should I say humankind. People have been dreaming of robots to serve humans in a personal sort of way for centuries — many years before industrialists came up with designs to assist workers in factories. I'd like to preface this article with an example of how a robot might serve man.**

I have long been a fan of the TV series, *The Twilight Zone* — especially the episodes of the early '60s. One of my favorite episodes was "To Serve Man" that appeared in 1962. It was based on a 1950 short story by Damon Knight.

Lying on a bed in some sort of cabin, the main character (Michael Chambers) begins with a narration to the TV audience of how he happened to be aboard a spaceship. The flashback begins at this point. Earlier, a race of nine foot tall aliens called the Kanamits landed on the Earth in a series of spaceships (flying saucers). After one of their kind appeared at the United Nations to profess their presence as entirely benevolent to the people of Earth, one Kanamit left a book at the UN before he left.

Seemingly true to their words, the Kanamit's advanced technology made barren deserts on Earth bloom with crops, cheap energy sources were developed, and wars became history. A few people were still not convinced until one of Chambers' staff of cryptographers cracked the 'code' to reveal the title of the book: *To Serve Man*. Well, everyone finally became assured that the aliens had come to do what they stated — to serve the people of Earth.

As the cryptographers continued decoding the rest of the book, people soon found themselves with little to do. They began accepting the alien's invitation to visit their planet and were leaving in droves on flying saucers for a vacation of a lifetime. With little to occupy his time, Michael Chambers decided to accept a trip to the Kanamit's planet, and as he was ascending the ladder of the spacecraft as shown in **Figure 1**, his assistant ran up to him through the crowd waiting to board.

**FIGURE 1. Twilight Zone episode 'To Serve Man' scene.**

Extremely agitated — and making the Kanamits agitated as well by her abrupt appearance — she yelled out, *"Mr. Chambers, don't get on that ship! The rest of the book, To Serve Man, it's ... it's a cookbook!"*

Chambers tried to run back down the stairs but was blocked by a Kanamit. The stairs retracted and the ship took off. You might say it was a kind of pizza delivery service for the Kanamits. The narrations to the TV audience continued at this point.

Obviously, we don't think our robotic creations are viewing us as a possible dinner. Looking at science

fiction movies, though, robots have long been presented as malevolent creations. Even after Isaac Asimov's Three Laws of Robotics came about and found their way into movies and stories, robots still found a way to be less than nice to us. The *Terminator* series and the Will Smith film, *I, Robot* still found ways to make robots very untrustworthy.

## How Can Robots Serve Mankind?

There are many ways in which a robot can serve humans. We'll just put aside the unpleasant scenario where one of our kind is served up as dinner. Instead, we'll focus on how some exceptional creations are designed and programmed to serve us in very unique ways.

Many of my previous articles have been about how we use robots for our own good — whether a specific robot that we've purchased to perform a certain task, or one that we've built from scratch for experimentation purposes. Other articles have been about robots in industry, the military, space and medical applications, and other non-personal uses.

I'd like to deviate a bit and discuss some unique robots that are making headlines around the world. Robots can 'serve' us in many positive ways, such as cleaning our floors and mowing our lawns. We can instantly imagine a robot butler of sorts, waiting on us as we sit in our living room watching the latest Robot Combat League episode. We can also envision an assistant for an elderly person who has a hard time just moving about their home. If we stretch our imagination a bit, we can envision a tennis-playing robot on the opposite side of the court from us, quickly darting side to side to hit the ball back to us. We may also dream of a video game that has come to life and given us a true robotic adversary with which to chase and destroy with our trusty laser ray gun. How about an 800+ pound robot to fight against an opponent of equal size and capabilities? Well, we have that now. Enter the Robot Combat League.

## Robot vs. Robot

Robots can serve humans for entertainment value, so I'd like to go into depth on this for just a bit. Dave Shinsel (whose robot, Loki I have written about for years) and his daughter, Amber recently won the new Syfy channel's Robot Combat League (RCL) competition. Dave lives just south of me in Portland, OR, and both father and daughter work at Intel in nearby Hillsboro. Both are software engineers. Dave and Amber (shown in **Figure 2**) formed Team Crash when they were given the orange 800+ pound 'walking orange roll cage' bot that is shown in a bout with the second place robot, Steampunk in **Figure 3**. These robot's service to Mankind may not be as a servant, but their entertainment factor is very high.

**FIGURE 2. Dave & Amber Shinsel in the Robot Combat League.**

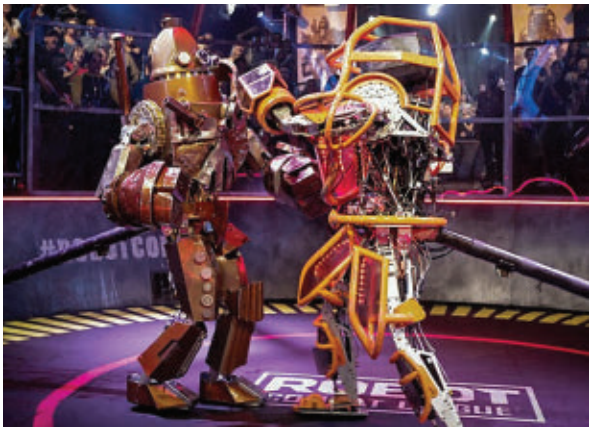

**FIGURE 3. Crash in bout with Steampunk.**

The Robot Combat League photos are courtesy of Mark Setrakian and **Syfy.com**.

Dave and his daughter started out at the bottom in early matches, but surprised everybody when they rose to be the ultimate winners of the combat series. Some people and the media have made jokes about the RCL as just another silly reality show with all flair and no substance, but Dave and Amber's experiences prove just the opposite. (Be sure and read Dave's article in this issue to get a real feel for their "real steel" experience.)

## Robot Combat League

Robot combat is accomplished by two similarly-matched 800+ pound hydraulically powered robots basically bashing each other to bits. When I talked with Dave after the final bout, he told me that the designer of the robots, Mark Setrakian, *"is a robot genius!"* Though not apparent to the audience because of the differences in armor and arm and leg coverings, each robot is structurally identical on the inside. All actuators and controls are the same, which makes for easier repairs during the bouts by the two technicians supplied to each team.

The robot 'Jockey' (Amber, in this case) controlled the arm motions via an exoskeleton that fed motion control signals to the robot's actuators. As the robot 'Tech,' Dave sat with two joysticks to control the robot's step length and speed, knee height, and direction of walking.

All humanoid robots find standing a bit difficult, especially when one is being pounded in the stomach by an opponent. To keep them upright, each robot is supported by a trailing "T" bar (or boom) to stabilize the robot, and to supply hydraulic and electrical power through a cable, along with control signals through fiber optic

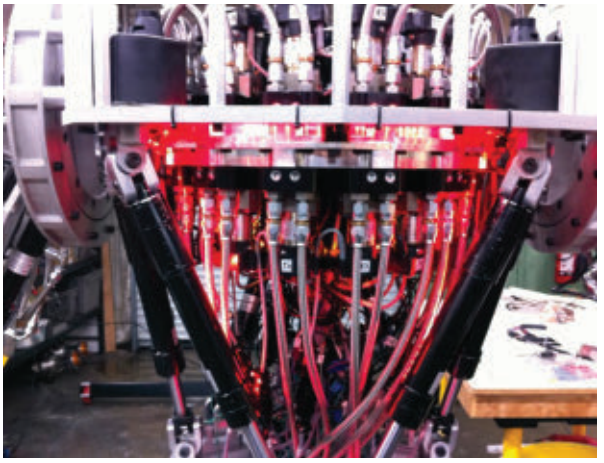

FIGURE 4. The waist actuators, hydraulic hoses, and control valves.

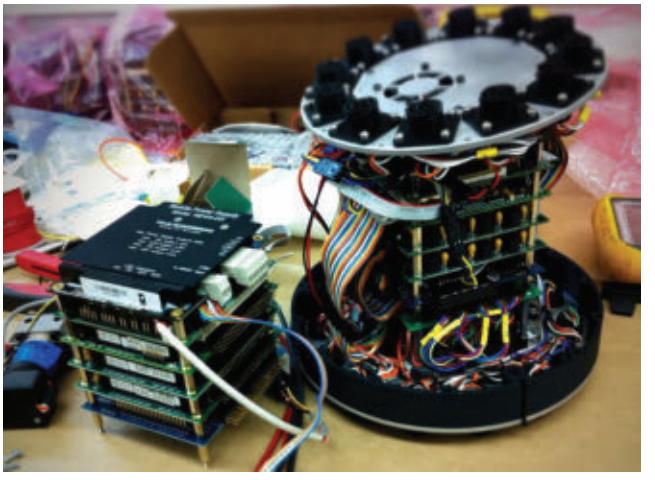

FIGURE 5. Robot's microcontroller for the 22 actuator valves.

FIGURE 6. RCL robot hydraulic actuator valves.

FIGURE 7. Beefy structural members, joints, and actuators.

cables. Most movies seem to teach non-technical people that all electrical things spew sparks when they fail (or get pounded by another robot). It appears that the robots are equipped with 'pyrotechnic generators' to dump a pile of sparks on the arena floor when the robot received a hard punch. However, the hydraulic fluid spraying out from a robot after a punch from an opponent was due to actual damage to the robot and not special effects, according to Dave.

FIGURE 8. Robo-cafe-restaurant with robot waiters.

## The Insides of Crash

Nothing tickles a robot builder more than to see the guts of a working robot — whether that be a teleoperated robot like Crash or Dave's 75 pound Loki. As the robot operators and repair crew, Dave and Amber got to see the real insides of their robot. It was nothing like the smaller robot action props like I built for *Revenge of the Nerds* and other movies; these RCL robots are massive and cost the producers about $200K each.

**Figure 4** shows just a glimpse of some of the waist hydraulic actuator cylinders and their associated 2,000 psi hoses connecting to the valve assembly above. These actuators send positioning feedback to the computer shown in **Figure 5** via potentiometers. **Figure 6** shows the rows of 22 very expensive valves that cannot be replaced, so are hidden safely behind their own armor. **Figure 7** illustrates just how robust the robots were constructed, with thick aluminum plate and beefy actuators. These robotic beasts are far more than a giant remote-controlled toy.

## Robots Serve Us ... Food

One of the ways that we can have a robot serve us is within the food industry — especially restaurants. The Korean company, ITM Technology has developed a robot restaurant waiter that can take orders both

FIGURE 9. Robots cook meals in a Chinese restaurant.

FIGURE 10. Robot waiter delivers meal to table.

FIGURE 11. Beverage robot assists a human in serving drinks.

FIGURE 12. Chinese noodle robots.

FIGURE 13. The future of food farming.

verbally and via a touch screen, and then deliver the food to each customer's table. Shown in **Figure 8**, the robot rolls out on a special runway to deliver food items from the kitchen.

As with most early robot installations in Korea and other countries around the world, robots were used in manufacturing and in jobs considered dangerous for humans. As the cost of living rose, the needed higher salaries of employees in all sectors of business caused company management to investigate the use of robots. Robowaiters do not require salaries, tips, vacations, and sick leave, though a bit of maintenance and a few squirts of oil may be appropriate from time to time.

## Robot Restaurant in China

The Robot Restaurant in Harbin in the northern Heilongjiang province of China has 20 different robots acting as waiters, cooks, and bus boys. There's even a robot singer to entertain the guests as they eat. Opened in June of last year, the restaurant has received world-wide acclaim.

Upon entering the restaurant, an usher robot extends its mechanic arm to its side and says 'Earth person, hello. Welcome to the Robot Restaurant.' The diners give their orders to a robot who then transfers the information to the kitchen to be prepared by several robot cooks (**Figure 9**). When the meal is ready, a robot waiter rolls along a special path (**Figure 10**) to bring the meal right to the table. The beverage robot shown in **Figure 11** is assisted by a human (or is it the other way around?). A singing robot rolls about the restaurant, entertaining the guests as they eat.

The robots cost anywhere from $31,500 to $47,000, and it will take many $6 to $10 meals to pay for the group of them — despite the savings over human workers.

Many Asian countries are rapidly arriving into the high technology age and are demanding fast food prepared with a modern twist. Chinese noodle robots (**Figure 12**) are used in preparing many types of noodles — a popular Asian dish. Other robots have been developed to prepare sushi — a delicacy that requires careful handling and special preparation techniques.

The robot 'exoskeleton' shown in **Figure 13** is another example of how robotic technology is assisting humans in food harvesting, preparation, and serving.

## Robot Burger Maker

I'm going to end this robot food section by discussing a robot that makes hamburgers. The Alpha machine shown in **Figure 14** from Momentum Machines in San Francisco, CA not only cooks up a great burger, but a custom-ordered

**FIGURE 14. Robot burger maker.**

one. It is designed to deliver "gourmet quality burgers at fast food prices."

The tasty burger is made from freshly-ground beef that is shaped and grilled to the customer's liking. Top quality toppings are applied, and the burger is wrapped and delivered on a small conveyor belt right to a window where the customer is waiting. No cashiers are needed as the customer punches in their order, swipes a credit card, and is virtually handed a hot and juicy burger prepared to their liking. Yes, folks. Food preparation has entered the robotics age.

## Robots Assist Humans in Their Homes

It's no secret about my interest in robots to assist the elderly and disabled. For many years, companies around the world have tried to develop autonomous robots to assist seniors in basic daily needs such as getting into and out of bed, using the toilet, food preparation, and other tasks. Some companies are close to a truly useful machine with functional arms that can physically assist a person or retrieve needed items.

On the other hand, some have dabbled in mobile robot devices that are no more useful than following the senior around his/her home to remind them to take their pills — a task that does not really require a mobile robot. The growing population of the elderly around the world is demanding affordable — yet truly functional — personal assistant robots.

**FIGURE 15. Fraunhofer IPA Care-O-bot.**

## Care-O-Bot 3

The Care-O-Bot® assistive robot is a development of the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) in Stuttgart, Germany. Shown in **Figure 15**, the Care-O-bot is the result of more than 10 years of development by the company on a mobile robot assistant robot to help humans in their daily life. This is their third in a series of personal assistant robots, and they use proven industrial components such as the Kuka arm to provide functionality, as well as dependability. According to the company, "The robot is designed as an interactive butler to be able to move safely among humans, to detect and grasp typical household objects, and to safely exchange them with humans."

I've followed the development of the Care-O-bot series for a number of years. The robust structure, drive system, quality, and basic design reminds me of the Willow Garage PR2. Birgit Graf of the Fraunhofer Institute states, "At the moment, we have our focus on so-called 'fetch and carry' tasks, so the robot is able to take an order. For example, 'bring me a drink to the kitchen' or 'bring me a drink to the living room.' It is able to navigate freely in the environment, find its way to the kitchen, identify the object on the kitchen counter, and bring it back to the user where it utilizes its tray to hand over the objects safely to the user."

"The robot can be controlled in three different ways, depending on a person's physical capabilities. The person in care can issue instructions via a smartphone or tablet-PC or, have a companion do it for them with a remote controlled device. Alternatively, the Care-O-bot can be controlled by employees of round-the-clock service stations, using built-in sensors on the machine to navigate and steer it remotely."

The cost has not been established but is probably in the same range as the PR2 (around $400K), which is beyond the range of affordability of the average senior. Personally, I believe this design comes as close to a truly functional robot aide for seniors as any I've seen, but the cost is still prohibitive. Affordability will come at some point, as the Fraunhofer Institute has long been in the forefront of robotics research and development.

## Final Thoughts

So, I started this article with a slightly twisted look at a way that mankind can be served. Robots will slowly begin to serve man in many more ways as the technology progresses. It is up to us robot experimenters to discover just how our machine will make its impact upon the world. SV

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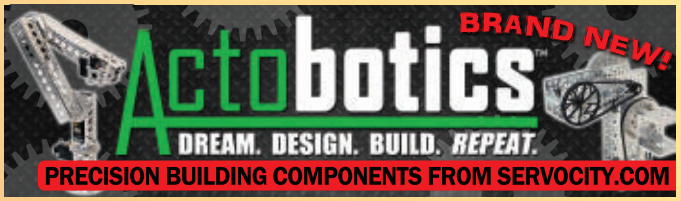

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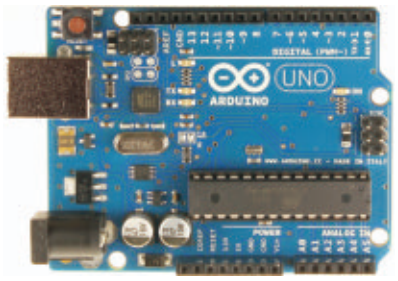

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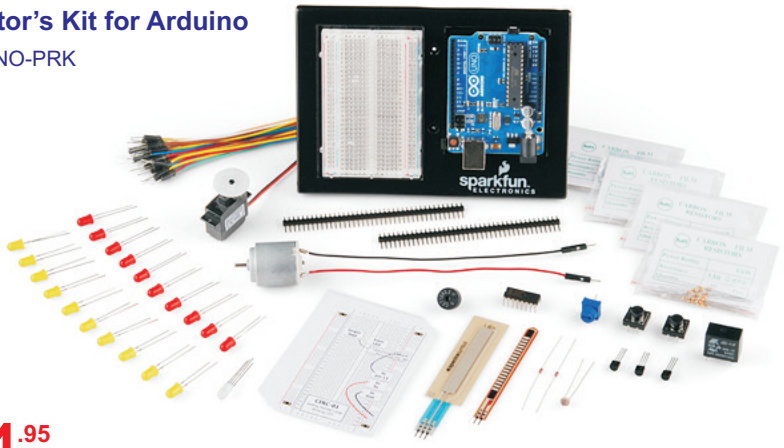

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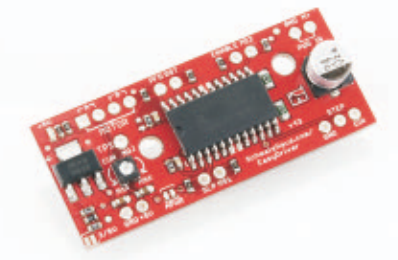

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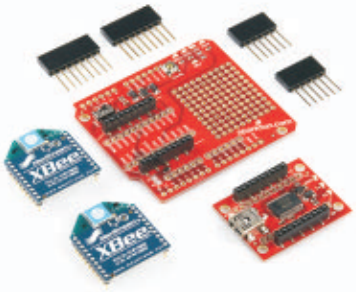

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| No load current | A | 0.61 | 1.06 | 1.18 |
| Continuous speed | RPM | 15.59 | 32.7 | 32.1 |
| Continuous torque | Nm | 5.596 | 21.142 | 39.131 |
| Continuous current | A | 1.989 | 5.930 | 9.505 |
| Resolution | Step/turn | 304,000 | 502,000 | 502,000 |
| Gear ratio | - | 304 | 502 | 502 |
| Backlash | arcmin | 3.5 | 3.5 | 3.8 |
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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gear Ratio (material) | 32 : 1 (enpla) | | | 254 : 1 (enpla) | 254 : 1 (enpla+metal) | 193 : 1 (metal) | | | 193 : 1 (metal) | 193 : 1 (metal) | 200 : 1 (metal) | | | 200 : 1 (metal) | 225 : 1 (metal) | | | 184 : 1 (metal) |
| Network Interface | TTL | | | TTL | TTL | TTL / RS-485 | | | RS-485 | RS-485 | TTL / RS-485 | | | RS-485 | TTL / RS-485 | | | RS-485 |
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| Motor | Cored Motor | | | Cored Motor | Coreless Motor | Maxon Motor | | | Coreless Motor | Maxon Motor | Maxon Motor | | | Maxon Motor | Maxon Motor | | | Maxon Motor |
| Operation Voltage (V) | 9.0 | 11.1 | 12.0 | 9.0~12.0 | 9.0~12.0 | 11.1 | 12.0 | 14.8 | 9.0~12.0 | 12.0~18.5 | 11.1 | 12.0 | 14.8 | 12.0~18.5 | 11.1 | 12.0 | 14.8 | 12.0~18.5 |
| Stall Torque (N.m) | N/A | | | 1.5 at 12.0V | 1.8 at 12.0V | 2.3 | 2.5 | 3.1 | 2.6 at 12.0V | 2.5 at 14.8V | 5.5 | 6.0 | 7.3 | 4.0 at 14.8V | 8.0 | 8.4 | 10.0 | 8.0 at 14.8V |
| Stall Current (A) | 1.1 | 1.3 | 1.4 | 1.5 | 2.2 | 1.3 | 1.4 | 1.7 | 2.4 | 1.5 | 3.9 | 4.1 | 5.2 | 2.1 | 4.8 | 5.2 | 6.3 | 6.1 |
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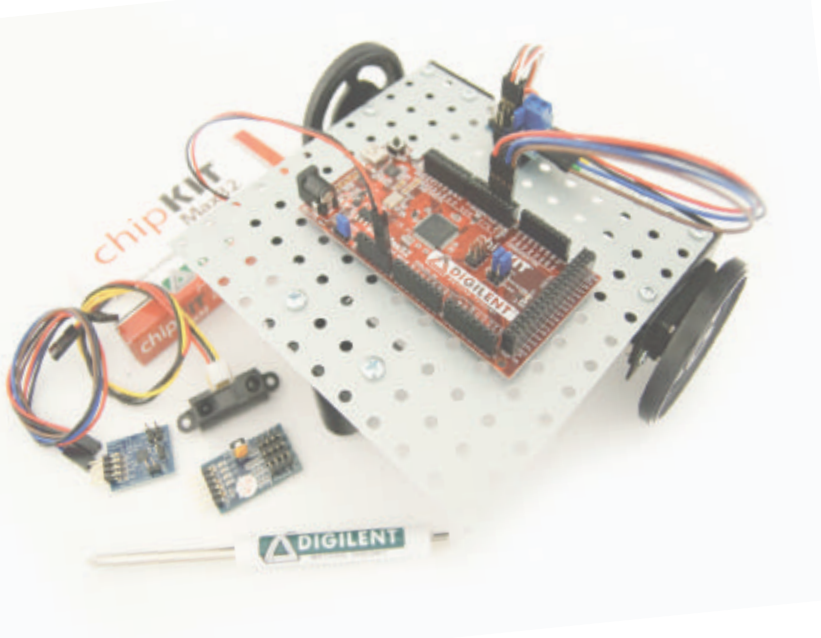


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- Compatible with many Arduino™ shields
- 83 available I/O
- User LED

## chipKIT™ uC32

**$34.99**

- Microchip® PIC32MX340F512H microcontroller
  - 80 Mhz 32-bit MIPS
  - 512K Flash, 32K SRAM
- Can also be programmed in Microchip's MPLAB
- Arduino™ "Uno" form factor
- Compatible with many Arduino™ shields
- 42 available I/O
- Two user LEDs

## chipKIT™ Uno32

**$26.95**

- Microchip® PIC32MX320F128 processor
  - 80 Mhz 32-bit MIPS
  - 128K Flash, 16K SRAM
- Can also be programmed in Microchip's MPLAB
- Arduino™ "Uno" form factor
- Compatible with many Arduino™ shields
- 42 available I/O
- User LED

## Network Shield™ $54.99

- **Usable with the Max32**
- 10/100 Ethernet
- USB Host, Device, OTG
- Dual CAN transceivers
- Dual I2C™ connectors
- 256kbit I2C™ EEPROM
- 32.768 Khz oscillator for RTCC

## Basic I/O Shield™ $37.99

- **Usable with the Max32, Uno32, & uC32**
- 128x32 OLED Graphic Display
- Digital temperature sensor
- 256kbit EEPROM
- 4 switches, 4 push buttons, 8 LEDs
- 4 Open drain transistor outputs
- Analog potentiometer

## Pmod Shield Uno™ $21.99

- **Usable with the Uno32**
- Five 2x6-pin Digilent Pmod connectors
- One 6-pin SPI connector
- One I²C daisy chain connector

## WiFi Shield™ $49.99

- **Usable with the Max32, Uno32, & uC32**
- IEEE 802.11b-compliant RF transceiver
- 1 and 2Mbps data rates
- IEEE 802.11b/g/n-compatible
- Integrated PCB antenna
- Micro SD card connector
- Four LEDs

## chipKIT™ PGM

**$26.99**

The chipKIT PGM is a simple, low cost, module that supports in-system programming and debugging of applications written for Microchip PIC based microcontroller boards such as the chipKIT™ and Cerebot boards. It is designed to work with the MPLAB® and MPLAB® X development environments available from Microchip.

The chipKIT PGM can also be used to enable in-system debugging of sketches developed using the Arduino™ compatible MPIDE development environment.

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